WADC TECHNICAL REPORT 57-477
PART I.
[redacted]

HIGH ALTITUDE BALLOON DUMMY DROPS

PART I. THE UNSTABILIZED DUMMY DROPS

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AERO MEDICAL LABORATORY

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WRIGHT AIR DEVELOPMENT CENTER

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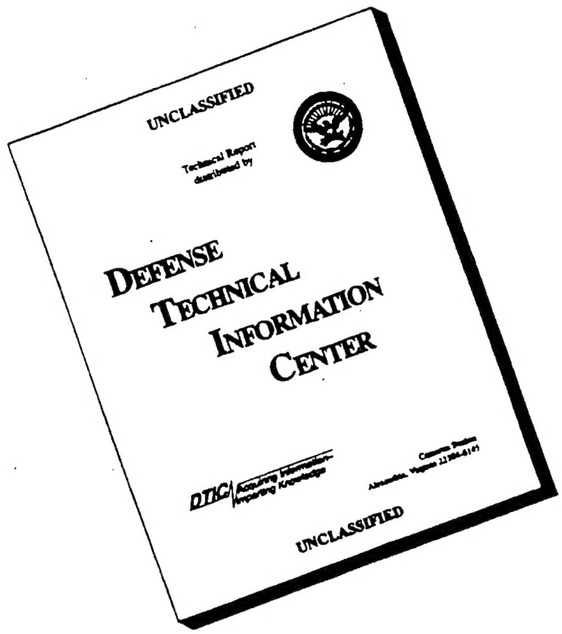

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FOREWORD

This study was made by the Escape Section of the Biophysics Branch, Aero Medical Laboratory of the Wright Air Development Center, with Lt. Edward G. Sperry, Lt. Gene M. Schwartz and Lt. Raymond A. Madson serving as project engineers. Authority for the work was Project 7218, "Biophysics of Escape," Task 71719, "High Altitude Escape Studies".

The dummy drops were divided into two phases. Phase I, described in this publication, was concerned with unstabilized drops. Phase II will be a study of the means of stabilizing the free-falling body.

This report was written by Lt. Raymond A. Madson, and physical preparation was done by Mrs. Loretta B. Carter and Mrs. Dora E. Weaver.

This report is UNCLASSIFIED.

ABSTRACT

The characteristics of instrumented dummies carried aloft to predetermined altitudes were studied during the free fall in unstabilized situations. These dummies were observed to assume an attitude permitting spins about a transverse axis, and the angular velocities recorded on accelerometers exceeded rates compatible with human tolerance. This study justifies further tests to develop a method of stabilizing a man descending from high altitudes.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Laboratories

SECTION I

INTRODUCTION

In July 1954, two British scientists, D. B. Cobb and M. H. L. Waters, published Technical Note No. Mech Eng. 179, "The Behaviour of Dummy Men During Long Free Falls", in which they reported that free-falling bodies of man-like configuration tend to assume a prone position parallel to the earth's surface and spin about a vertical axis. Due to the complexity of higher altitude escape problems arising from high performance aircraft, the British report justifies further tests from high altitude. More explicit data are needed on the characteristics and magnitudes of the rotational motion encountered in a free fall, but information is required for much higher altitudes than the 30,000 feet reported on by the British scientists.

A free fall is considered necessary, because:

a. Parachute opening shock at high altitude might injure the man or damage the parachute.

b. Extreme cold of high altitude makes it imperative that a man fall to lower altitude and warmer temperature without loss of time, thereby reducing the chance of death or injury resulting from cold or exposure.

c. A large oxygen supply would be needed for a slow descent.

d. Slow descent might result in death or injury from exposure to low atmospheric pressure.

The Aero Medical Laboratory of Wright Air Development Center assumed the responsibility of making a study of this problem. To conduct the proposed study, many factors were considered; test location, dummies, instrumentation, photo coverage, recovery equipment and methods, test vehicles and techniques, data reduction, and any accessory aids necessary for the accomplishment of the over-all mission.

Coordination of support and selection and design of equipment were begun in March 1953, and, as work progressed, laboratory and low altitude live and dummy tests were conducted on the equipment. In February 1954, when it was felt that the equipment was ready for high altitude checks, a dummy and live jump program using a C-97 was scheduled. Following this program, the Balloon Dummy Drops were conducted and completed up to Phase II, "The Stabilized Dummy Drops".

This report considers the factors mentioned above, modifications of various systems and techniques, results of tests, and a final evaluation of Phase I, "The Stabilized Dummy Drops".

SECTION II

METHODS AND RESULTS

TEST VEHICLES

Polyethylene balloons, filled with helium, were the only vehicles capable of obtaining altitudes desired for the dummy drop tests. Various types and sizes of balloons were used throughout the project, as will be noted under "Test Results". General Mills TT balloons were most commonly used in the later stages of the project for three main reasons.

a. A great deal of experience had proven these balloons very reliable.

b. The payload-altitude capabilities were more economical than smaller balloons, in that two dummies could be carried to the desired altitudes at less expense than would be incurred by using smaller balloons carrying one dummy per balloon.

c. The Air Force already had a stock of the General Mills 128' TT balloons which were readily available for this project.

Use of balloons had safety limitations, however, which were concerned with the launch, flight, and recovery areas. These limitations influenced selection of the test site.

TEST SITE

For a test site, a large, relatively uninhabited area with mild climatic conditions was needed. Other requirements were supporting agencies with capabilities of furnishing adequate support in:

a. Maintaining the instrumentation and equipment,

b. Packing the parachutes,

c. Providing photographic coverage and service,

d. Launching the test vehicles,

e. Making the recovery,

f. Providing any other support necessary for completion of a mission.

Of the possible locations discussed, Holloman Air Force Base, New Mexico appeared most suitable and capable in nearly all respects, and was therefore selected.

DUMMIES

Anthropomorphic dummies with controlled movement of limbs and appendages, and resembling a 95 percentile man, (height - 72 inches, and weight - 200 pounds) were used in these tests. Weight distribution and body configuration were very similar to that of an average man of relatively large stature. (Fig. 1).

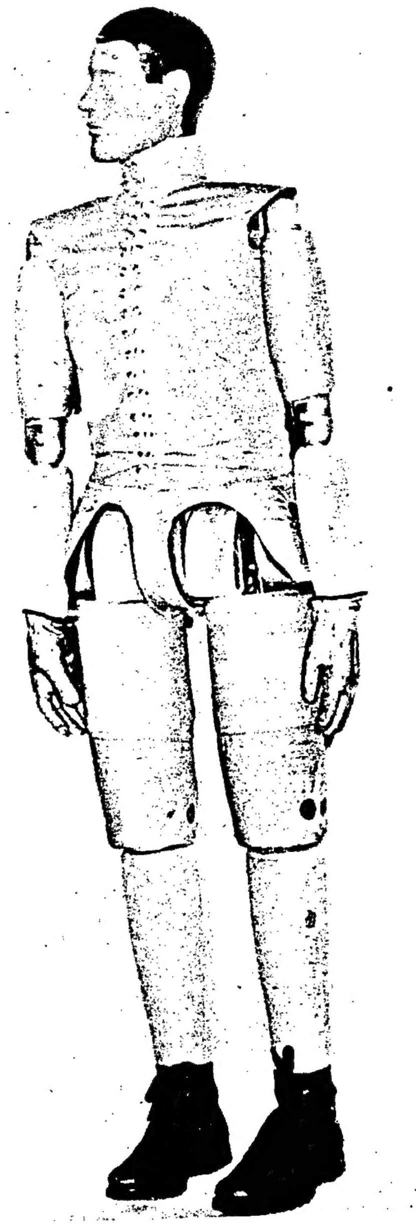


Figure 1. Test Dummy

INSTRUMENTATION

The dummy instrumentation kit consisted of:

a. One N-6 GSAP gun camera modified to run 8 frames per second using a 5° shutter. The camera was equipped with an 84° wide-angle lens. A 50-foot magazine of 16 mm daylight Kodachrome film was used.

b. Eleven recording accelerometers, eight in a survival type kit, and three mounted along the dummy's back. (Fig. 2).

c. One 14-channel Century Model 409 Oscillograph, eleven channels receiving transmissions from the accelerometers, one serving as a voltage trace, and two recording time-reference blips.

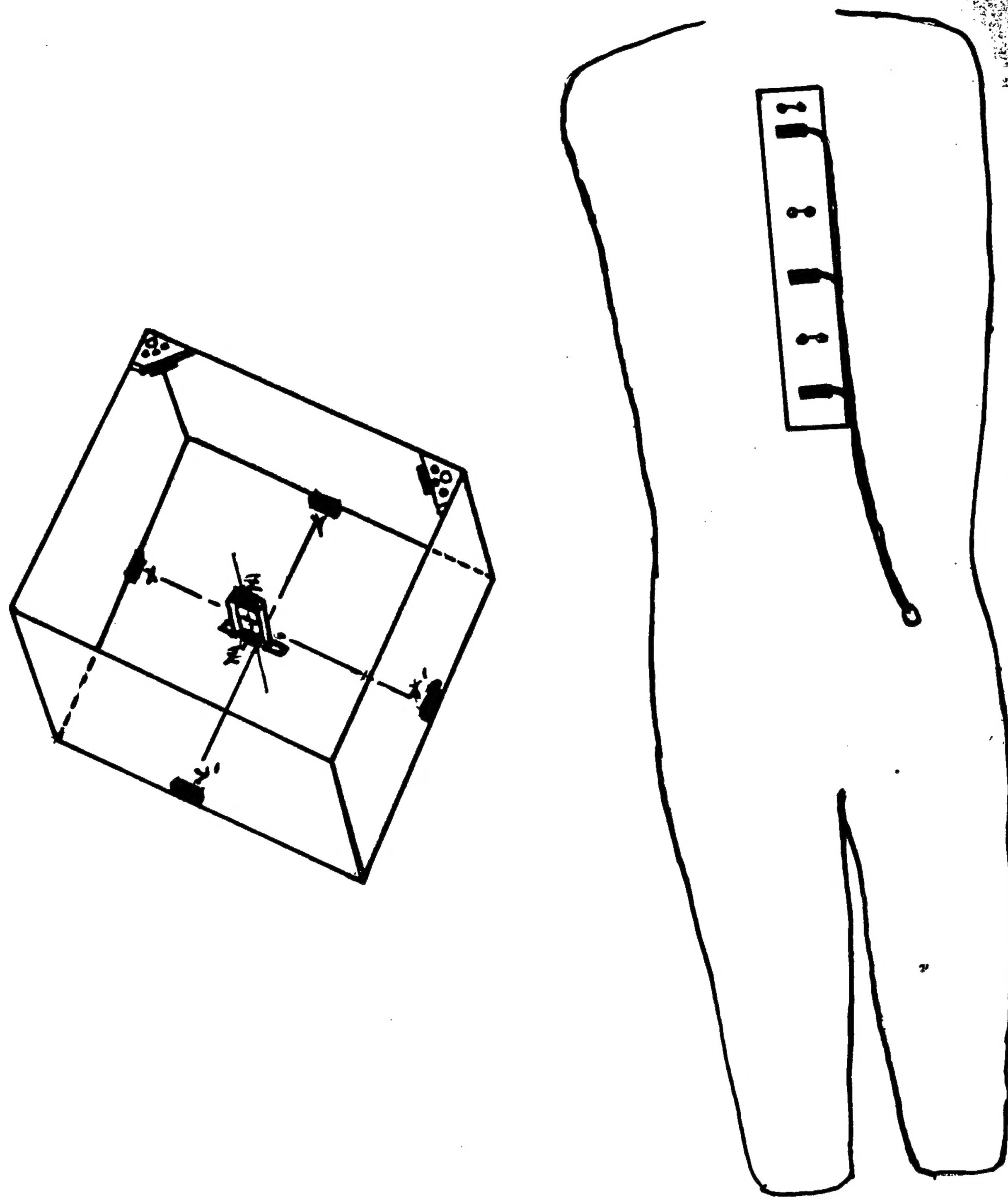


Figure 2. Placement of Recording Accelerometers

d. Eighteen HR-1 Silvercel batteries which supplied power to fire the uibs at cut-down, run the camera and oscillograph, and furnish voltage for the celerometers,

e. One modified Brailsford timer to sequence cut-down and operate a tching relay,

f. One g-proof latching relay to turn on the recording instruments and, ter the free fall was completed, turn the power supply off.

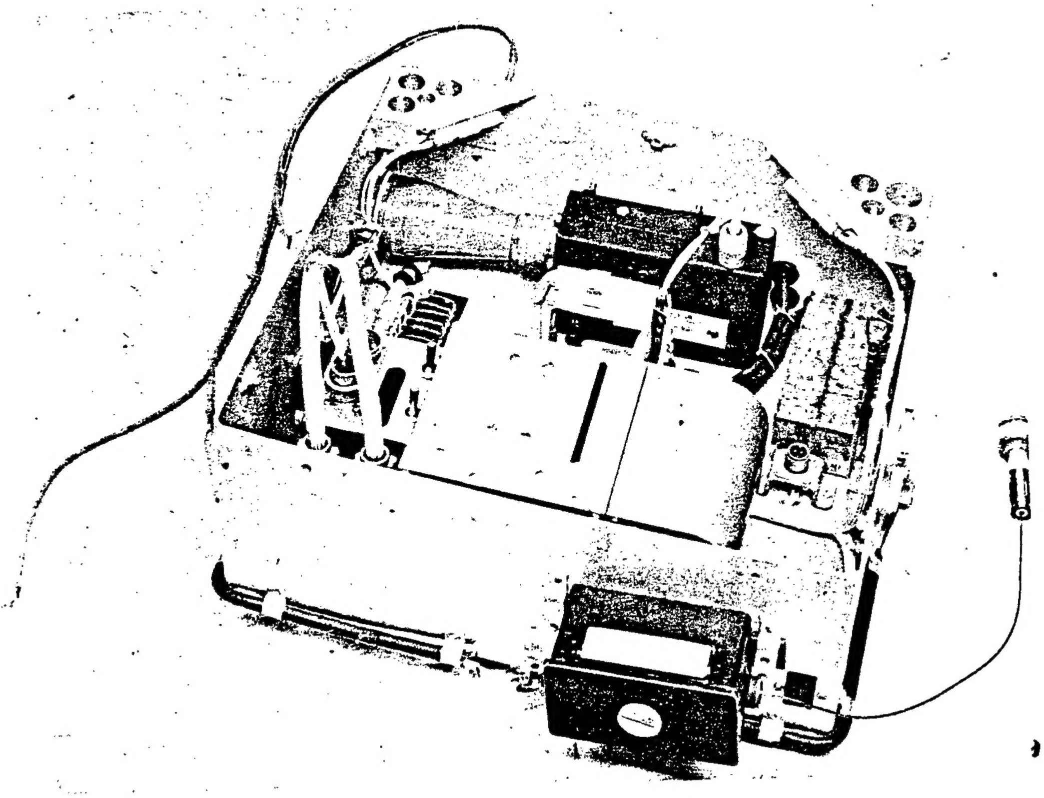


Figure 3. Instrument Kit with Instruments

All dummy instrumentation was contained in a survival type kit, (Fig. 3), with the exception of the three accelerometers mounted on the dummy's back. The kit was attached to the saddle of the parachute harness with two quick-release clamps, one on either side of the kit. These clamps were activated to release the kit from the dummy at a preset altitude by a class F-1A timer installed on the bottom of the kit. Upon separation from the dummy, the kit would descend on its own parachute.

The balloon instrument box, which accomplished cut-down, contained its own power supply, (batteries), a radio receiver through which the cut-down command was transmitted to the dummy's instrument kit, a mechanical clock cut-down system to

override radio command failure if it occurred, a barometric safety device which would effect cut-down automatically if the balloon rose above 30,000 feet and started to descend, and any other equipment required for the flight. The balloon cut-down box recovery parachute, flown open, was an 18 to 24 foot cargo parachute.

CALIBRATION OF INSTRUMENTATION

In order that the data reduction agency would have a standard with which they could correlate the raw data for reduction, a calibration was run on the instrument kit prior to every launch. The calibration was also used as a visual check to determine whether or not the instruments were functioning properly in the laboratory.

The data reduction agency's requirements were that they have a record of the dummy (instrument kit) in as many positions as possible. Accordingly, a standard calibration check list was devised, (Fig. 4), and this form was followed strictly for every calibration to maintain congruity.

CHECK LIST

Flight Data

Pre Calibration

2 Galvanometer plugs in

1 remote plug in

Off - ON Switch ON

Fuses OK 8, 4 and 1 amp

Main Power External on

Paper Capacity, feet, full

Light intensity 6-29V, 1-20V

Test Box plug in

GSA plug Out

Calibration (run 5 to 6 seconds)

Run #1. Zero Voltage. Apply 24-28 Volts to oscillograph power plug.
#2. 24-28 Volts Cal. Apply 24-28 Volts to Kit and oscillograph.________Volts.
#3. Bottom down and feet down
#4. Top down and head down
#5. Right down and Back down
#6. Left down
#7. Fore down
#8. Aft down
#9. Shaking

Figure 4. Calibration Check List

To attain the desired dummy (kit) position as accurately as possible, a two-layer metal plate, metal dowel pins, and a level were used. The top layer had many variously spaced holes in which the pins could be inserted. For calibration, the pins were positioned, the kit placed on the pins and leveled, and then the oscillograph turned on for a period of 6 to 8 seconds. This procedure was followed for every kit positioned until the last run, at which time the kit was shaken vigorously as the oscillograph was recording.

On completion of the calibration, the record was developed and inspected to insure that all recording instruments in the kit were functioning properly. This accomplished, a fully loaded film magazine was installed on the oscillograph, and the kit was ready for the final preparation and check in the laboratory.

After the flight and recovery of the packages, the raw data, plus the calibration, were transmitted to the data reduction agency.

PHOTO COVERAGE

In the initial phase of the Dummy Drop Tests, black and white still photos of all items used in the over-all system and launch were taken. This included, in order: the open instrument kit; the closed, ready-to-fly kit; the ready-to-fly dummy with kit and parachute; launch preparations; and the actual launch. As the project progressed, this practice was discontinued and the black and white stills were taken only when major modifications of the system or equipment were made.

Preparations at the launch site and the launch itself were recorded on 16 mm daylight Kodachrome.

In a few instances, photographic coverage was obtained on recovery of the equipment, but due to the inconsistency of the flights and the uncertainty of time and area of recovery, manpower problems made this type of coverage infeasible. Therefore, it was not commonly requested.

ACCESSORIES

Due to the extremely cold temperatures encountered at high altitudes, it was originally believed that insulation for the instruments would be needed. For this, a large, black, insulated bag with a small opening in the top through which the dummy-balloon attachment could be made, was used, (Fig. 5). The bottom of the bag was tacked shut with a light-weight break-cord which allowed the dummy to drop free when it was released at altitude.

It was decided that the black bag absorbed too much heat, and a silver colored insulation bag was adopted, (Fig. 6). In the ensuing tests no data was obtained, as the instrument kits and kit-dummy connections were torn loose, apparently at let-down. It was felt that this damage resulted as the dummy broke through the bottom of the bag, and the practice of using insulation bags was therefore abandoned.

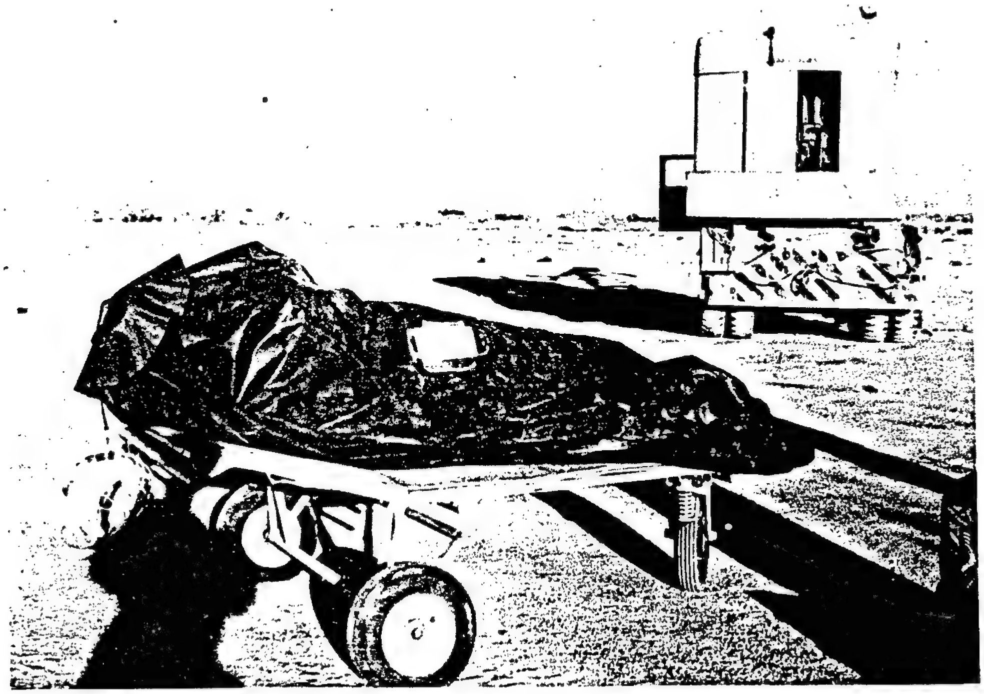


Figure 5. Insulation Bag Showing Balloon Attachment Hole.

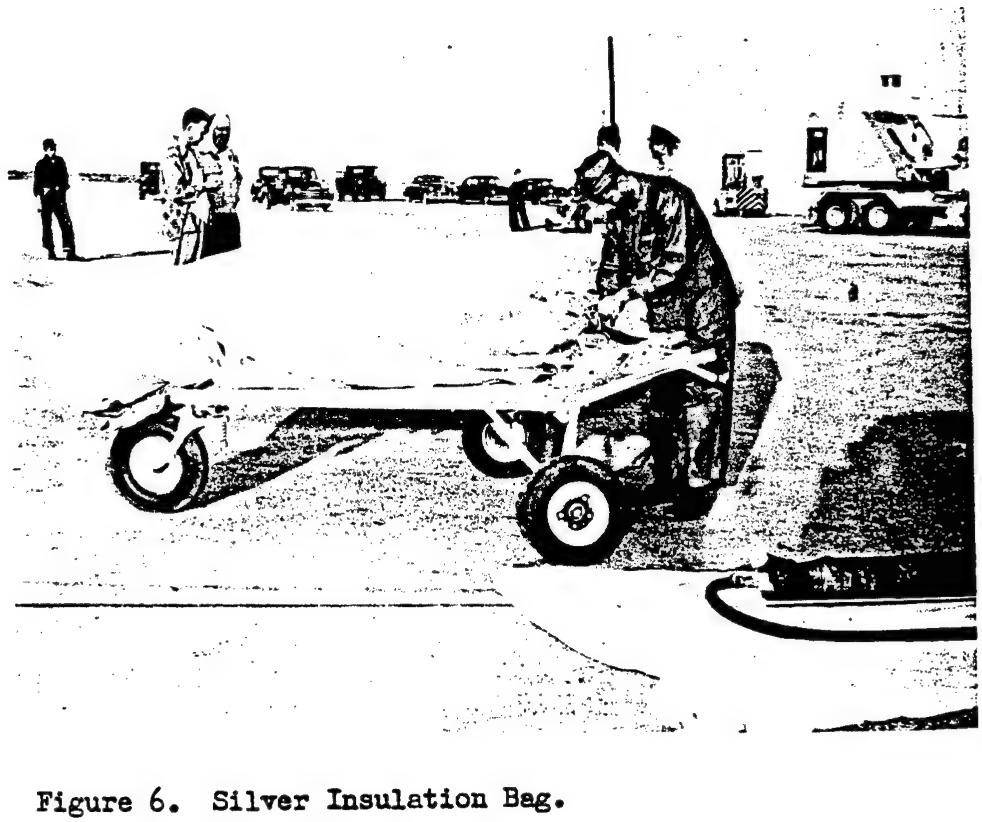


Figure 6. Silver Insulation Bag.

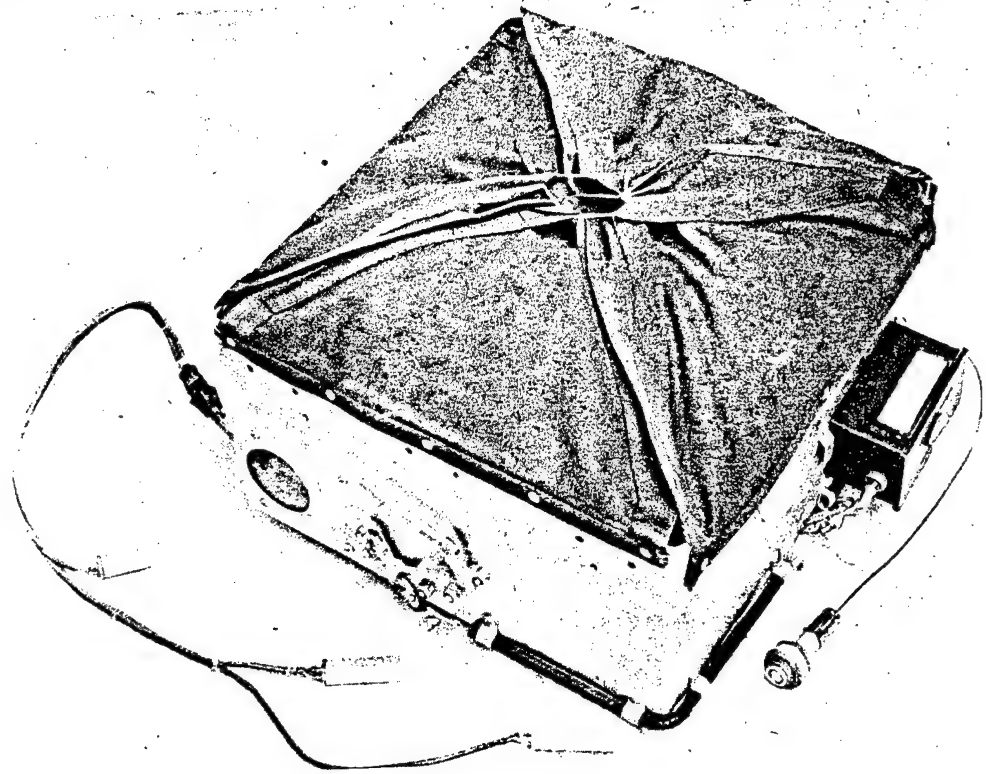


Figure 7. Kit Parachute, Packed in Lid.

PARACHUTE ASSEMBLIES

Three recovery parachutes were used on the dummy drops:

a. The dummy recovery parachute was a standard B-4 pack with a C-11 canopy. The parachute was activated at a preset altitude, (15,000 ft. MSL) by a Class F-1A timer installed in the pack and armed by a static line at cut-down.

b. The instrument kit recovery parachute was a standard 16-foot cargo parachute packed in the lid of the kit. (Fig. 7). This parachute was deployed by static line upon separation of the kit from the dummy at 12,000 feet MSL. The static line was attached on one end to the apex of the parachute, and on the other end to a V-ring installed in the B-4 harness. Kit lid flaps retaining the parachute in the lid were tied shut with relatively strong break-cord threaded through a cutter installed in the static line. The static line was tacked to the retainer flaps to prevent it from becoming entangled with the dummy.

c. The balloon cut-down box recovery parachute, flown open and attached to the balloon, (Fig. 8), was an 18 to 24-foot cargo parachute, the size depending on the payload of each mission.

A dummy chest reserve parachute was also used in the initial drops to give the free-falling dummy a more realistic configuration, but it was found that the reserve did not affect aerodynamic forces in the fall, and use of the reserve was discontinued.

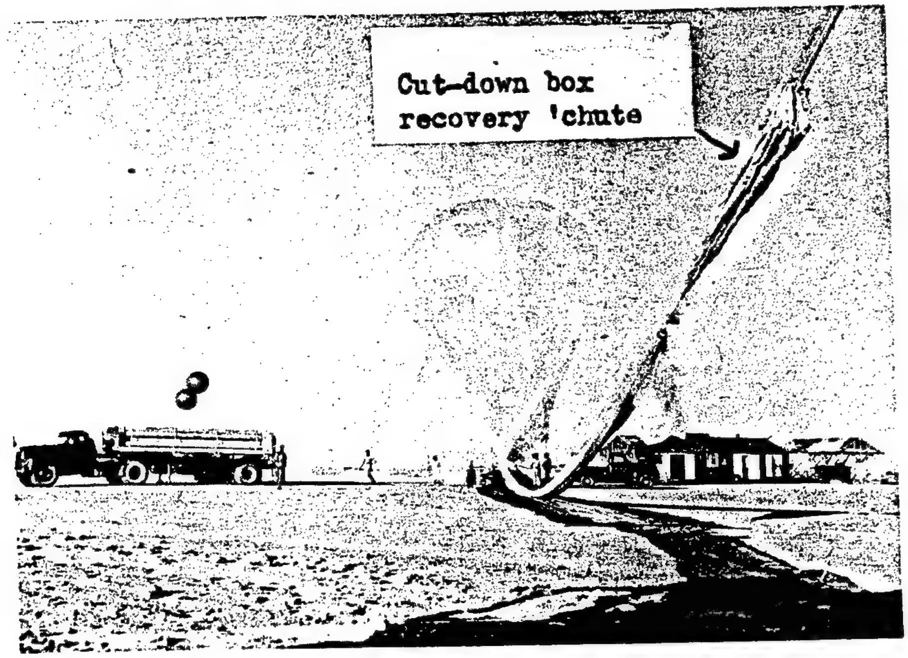


Figure 8. Cut-down Box Recovery Parachute

LAUNCH TECHNIQUES

Three different launch techniques were used in the dummy drop program:

a. Platform Launch - The balloon was stretched out on a canvas strip over the ground. The upper portion of the balloon was fed through a pair of launc arms resembling a washing-machine wringer. The balloon-inflation tube, through wh the helium was transported, fed into the upper portion. The balloon instrument bo attached to the lower end of the balloon, and the instrumented dummies, resting on a three pivot-wheel cart, (Fig. 9) were connected below the instrument box. When the balloon was inflated and the inflation tube tied off, the launch arms were released, allowing the balloon to ascend, (Fig. 10). As the balloon rose, it lifted the dummies off the cart. The three pivot-wheels were a safety factor in the event the balloon did not rise directly in a vertical position, but tended to ascend at an angle. However, the cart did not function in the manner intended, and after many of the dummies launched by this method were dragged along the groun this type of launch was discontinued.

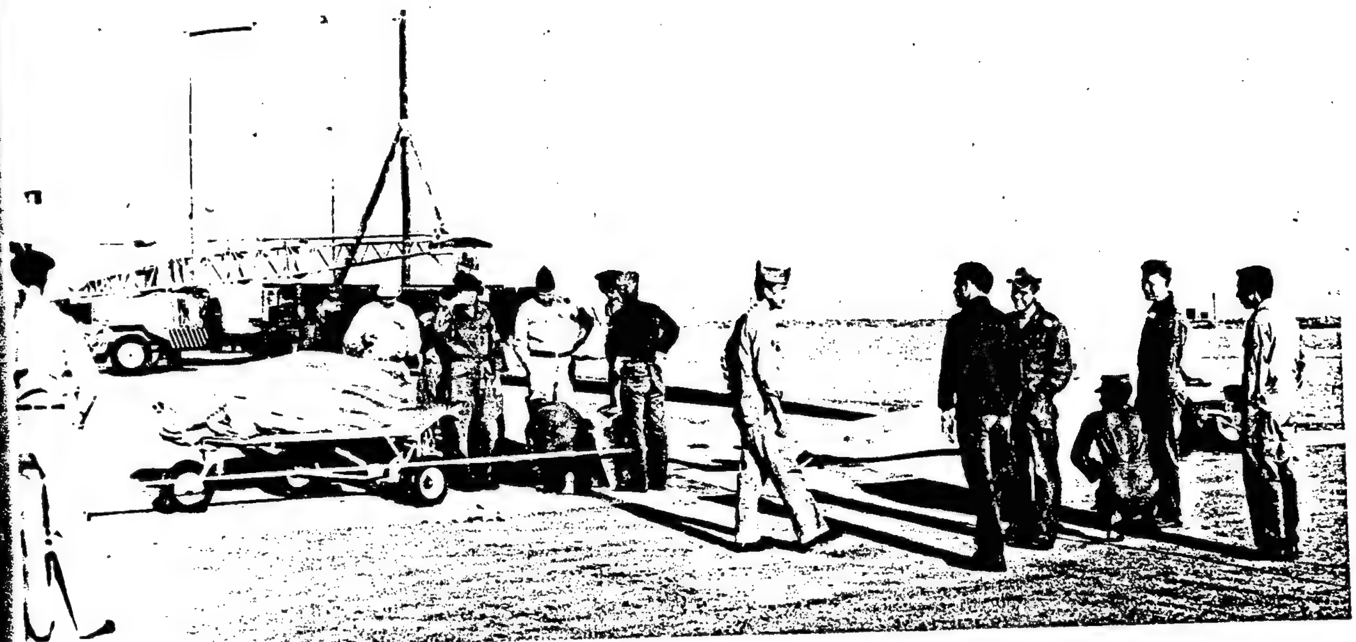


Figure 9. Three-Wheel Launch Cart.

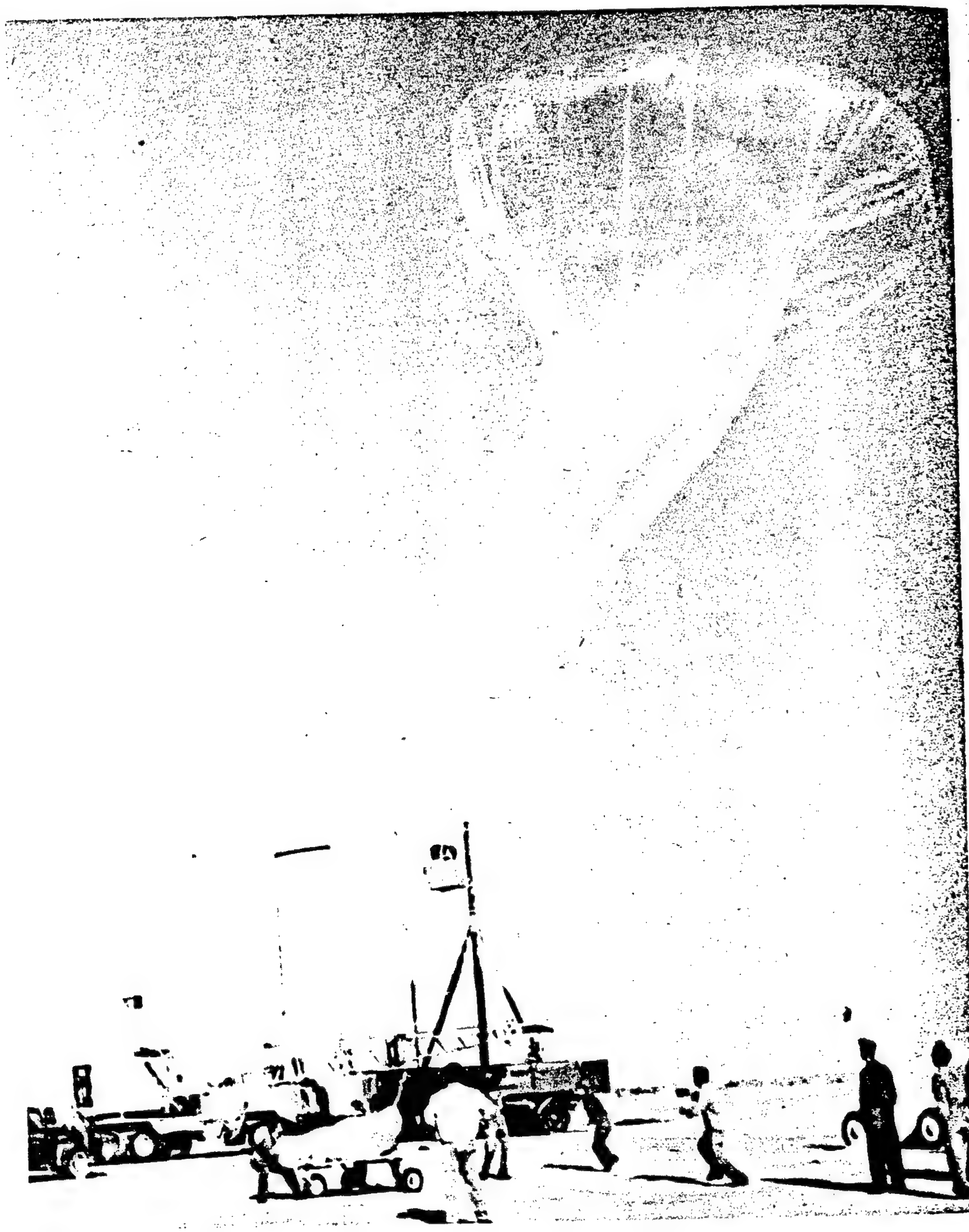


Figure 10. Platform Launch.

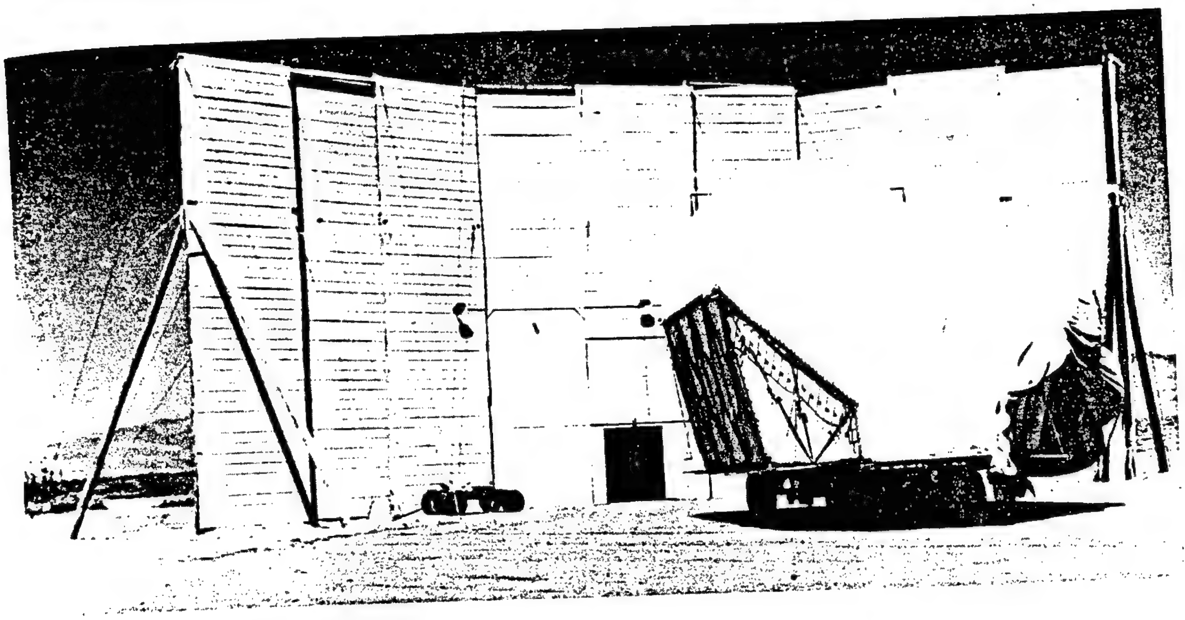


Figure 11. Covered Wagon.

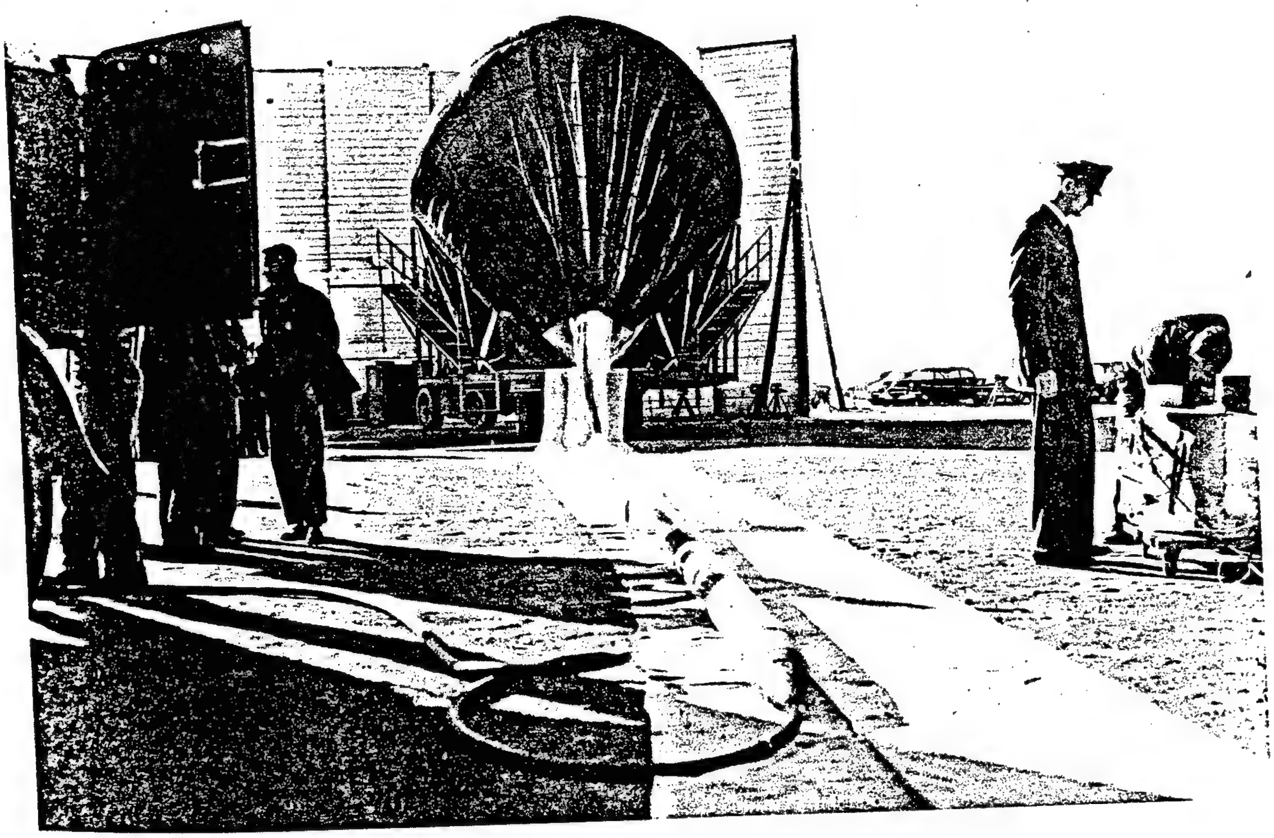


Figure 12. Covered Wagon - Balloon Inflated.

b. Covered Wagon Launch - The "Covered Wagon" was a large, canvas-lined trailer,(Fig. 11) in which the top portion of the balloon was inflated, (Fig. 12). The dummies, as in the Platform Launch, were resting on a three-pivot-wheel cart and attached to the bottom of the balloon instrument box, which, in turn, was connected to the bottom end of the balloon. The launch was effected by releasing one side of the canvas serving as the cover over the wagon. When the canvas was released, the balloon was freed and ascended, (Fig. 13) lifting the dummies off the cart. This technique resulted in too many abortions by apparently causing small pinhead leaks to develop in the balloon, resulting in unsatisfactory altitudes on the drops.

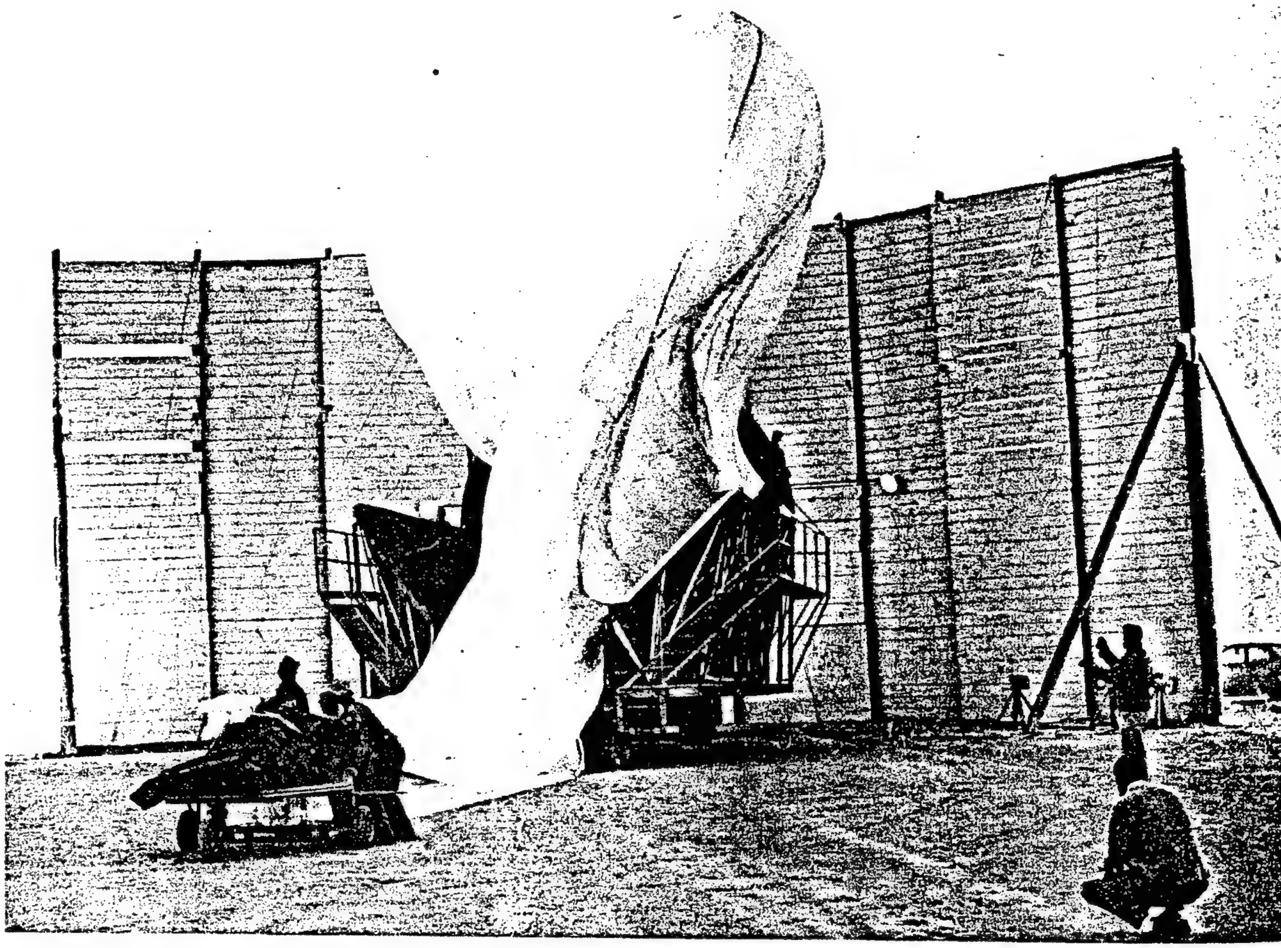


Figure 13. Covered Wagon Launch.

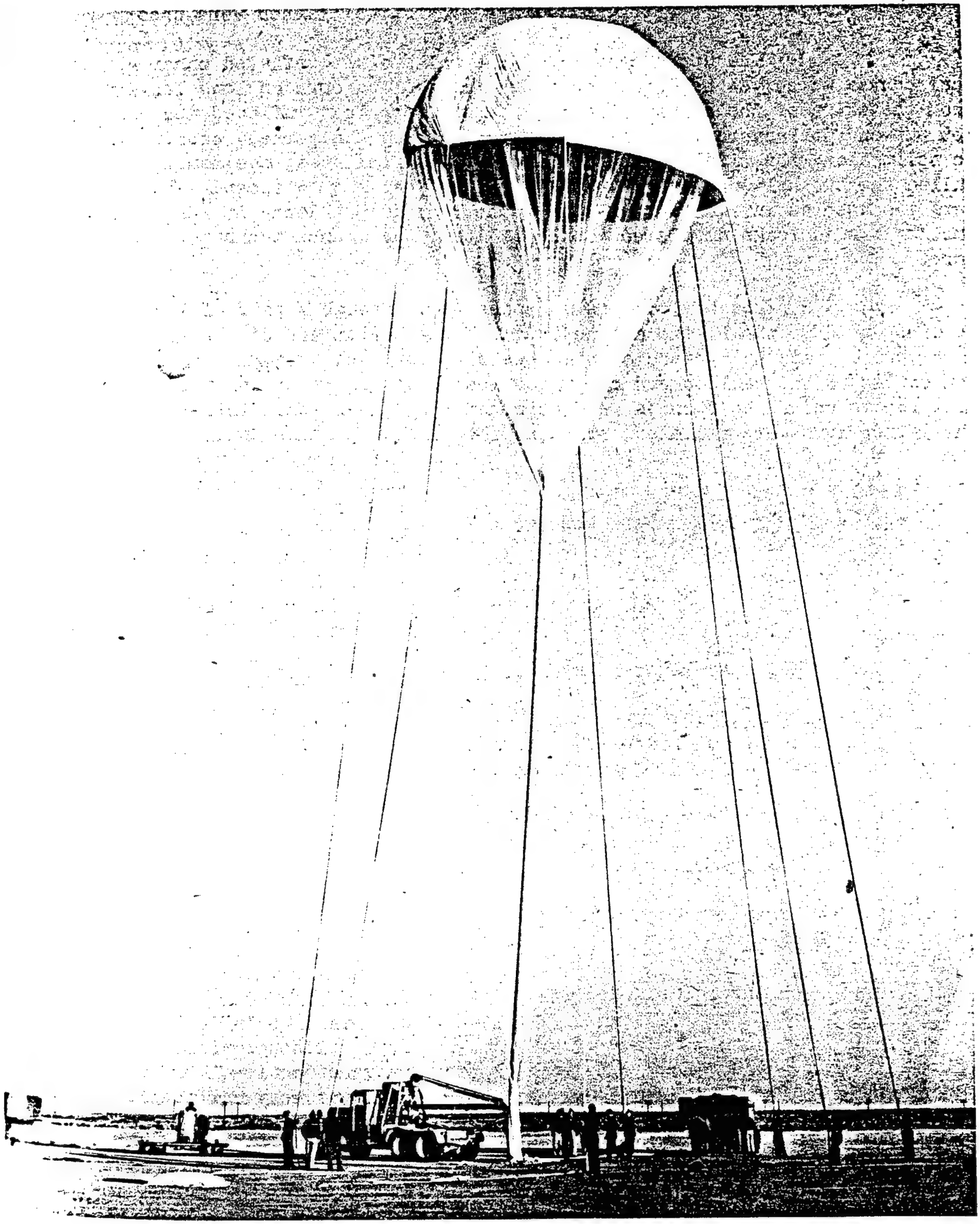


Figure 14. Vertical Launch Technique

c. Vertical Launch - Two types of vertical launch were used:

1. The upper portion of the balloon was inflated under a half spherical canvas which was held stationary by men pulling down on long lanyards extending from the skirt of the canvas (Fig. 14). As the balloon inflated and rose, the men let out on the lanyards. At launch, a pull-string was jerked, causing the canvas to split along the middle seam, and as the seam separated, the men on the lanyards pulled the two halves clear, thus allowing the balloon to ascend. The same launch cart was used as in the two previous types of launch. Since it was again noted that small pin-head leaks developed in the balloon, the launch technique was modified once more.

2. The balloon was stretched out through a pair of launch arms similar to those used in the Platform type launch. The bottom end of the balloon was attached to a mobile crane by a piece of nylon webbing threaded through a squib-fired cutter. Connecting to the balloon and hanging below it on the crane was the balloon instrument box to which the dummies were attached (Fig. 15). When inflation was complete, the launch arms were released, allowing the balloon to rise until it was arrested by the crane. In windy conditions the crane would move with the wind until the balloon was in a vertical attitude, and then the squib was fired, cutting the balloon, with attached equipment, free. If little or no wind prevailed, the crane would be positioned for the best ascent angle, and launch would be effected with the crane stationary. This type proved to be the most dependable launch technique for the remainder of the tests.

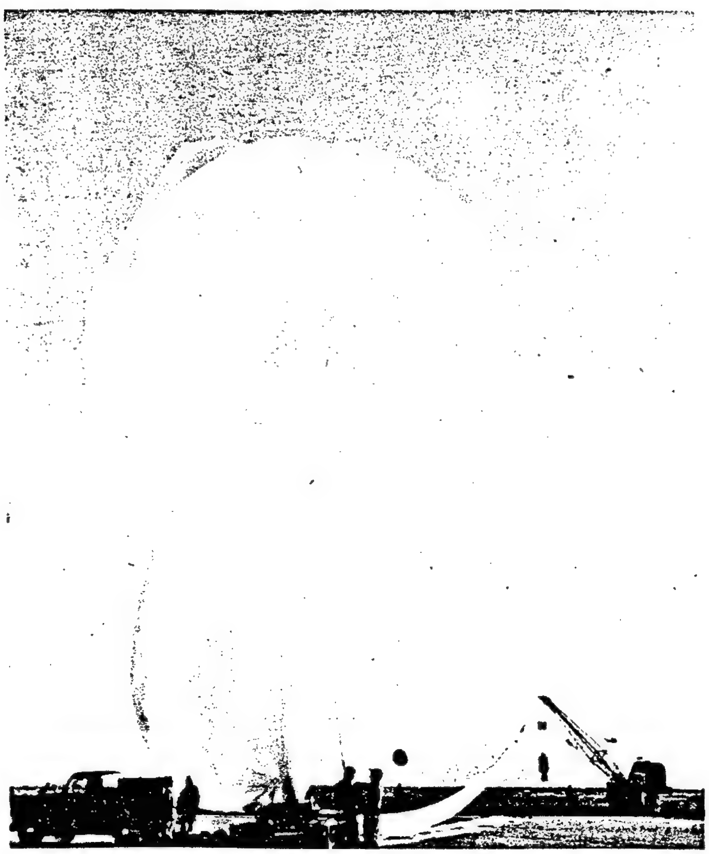


Figure 15. Modified Vertical Launch

RECOVERY AIDS

Initially, a modified M-18 red smoke grenade and a 5-pound bag of red pigment powder were to be used to aid tracking and recovery of the dummy and instrument kit, but these did not prove reliable. The dummies were dressed in fluorescent red flying suits, and colored parachute canopies were used to further facilitate recovery. Although visual tracking did not prove effective, the suits and canopies were very satisfactory.

Recovery notices offering $25.00 reward were attached to each dummy and instrument kit, (Fig. 16), to increase incentive to return the packages, in the event some disinterested or uninformed person located any of the equipment. Local newspapers and radio stations were asked for support if equipment became lost.

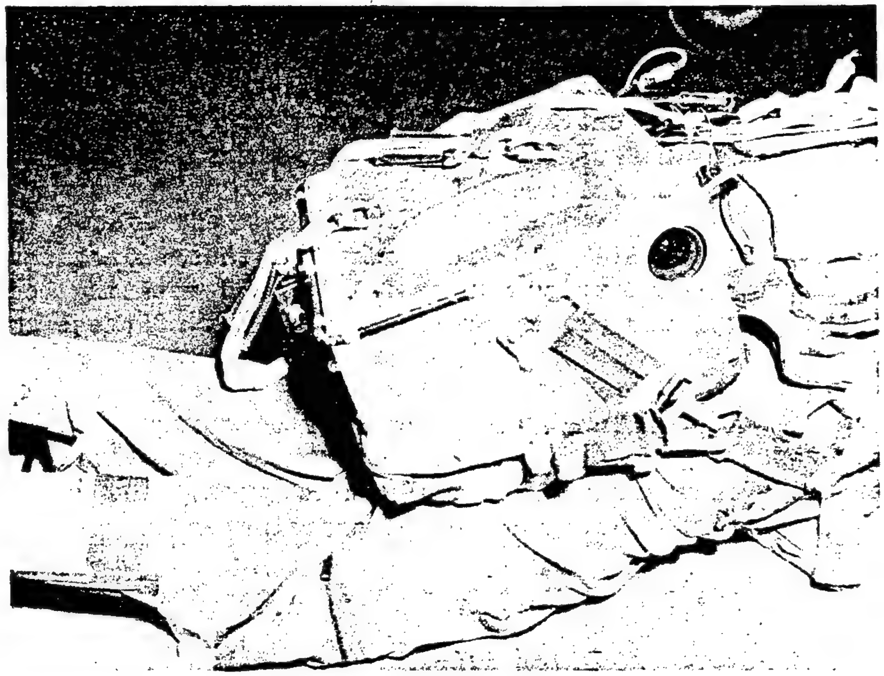


Figure 16. Recovery Notices, Dummy, and Instrument Kit

RECOVERY

Recovery support was obtained from two sources:

a. The HADC Balloon Unit recovery crew, which consisted ideally of:

1. Three aircraft - one C-47, T-33, or F-94, for higher altitude tracking; and two light aircraft, (L-20's), for lower altitude tracking and marking of package impact points.

2. Three ground recovery vehicles and crew located triangularly around the impact area, in order to establish a fix on the descending equipment, and pick it up as it impacted.

3. Radio contact maintained between all ground vehicles and aircraft throughout the entire mission.

This ideal recovery crew was not always available, and consequently variations of the system were used.

b. The civilian residents of the area. These were any individuals on whose land the equipment might impact, or persons who might, by chance or otherwise, find the packages. Liaison was accomplished with these persons by means of the recovery notices mentioned previously.

After completion of the mission, the oscillograph, camera film and the calibration record were sent to the University of Dayton, Dayton Ohio, for reduction and presentation in a usable form. The methods and formulas used to accomplish this reduction are as follows:

PURPOSE: (1) To derive the theoretical equations necessary to predict the angular velocity of a free-falling and rotating body and the center of rotation of that body, and (2) to prove the validity of these equations under known geometric conditions.

Consider a fixed system of coordinates X, Y, Z, and another system of coordinates x, y, z, rotating about the fixed system. Consider a point p placed somewhere in space with coordinates x, y, z. The acceleration of that point p with respect to the fixed set of coordinates is given by the equation

$$(1) \quad \vec{a}_f = \ddot{r}_o + a_m + 2w \times v_a + \dot{w} \times r_m + w \times (w \times r_m)$$

Where $\ddot{r}_o \equiv$ the linear acceleration of the origin of the rotating system with respect to the fixed system;

$a_m \equiv$ the acceleration of point p with respect to the origin of the rotating system;

$w \equiv$ the angular velocity of the rotating system;

$v_a \equiv$ the linear velocity of point p with respect to the origin of the rotating system;

$\dot{w} \equiv$ the angular acceleration of the rotating system;

$r_m \equiv$ the distance of point p to the origin of the rotating system.

If, however, point p is rigidly attached to the rotating system, then

$v_a = a_m = 0$, and equation (1) becomes

$$(2) \quad a_f = \ddot{r}_o + \dot{w} \times r_m + w \times (w \times r_m)$$

Equation (2) is the basic equation.

Consider six points in space, two points on each of the x, y, z axes. The following notation will be used:

$a_1\,(x)$ will denote the acceleration of one point on the x axis in the x direction;

$a_1\,(y)$ will denote the acceleration of a point on the x axis in the y direction;

$a_1'(x)$ will denote the acceleration of the other point on the x axis in the x direction.

In other words, the subscripts 1, 2, 3 will refer to the x, y, z axis, respectively, on which the point is placed and the letter in ( ) will determine the direction of that acceleration. All accelerations are with respect to the fixed coordinate system. Similarly, $r_1(x)$ is the distance from the point placed on the x axis in the x direction, to the center of rotation.

Using the above notation, equation (2) can be broken into its three components

$$(3) \quad a_1(x) = \ddot{r}_x + \dot{w}_y r_1(z) - \dot{w}_z r_1(y) + w_x \left[w_y r_1(y) + w_z r_1(z)\right] - r_1(x)\left[w_y^2 + w_z^2\right]$$

$a_2(y)$ can be found by replacing x with y, y with z, and z with x in equation (3) and similarly for $a_3(z)$. In equation (3) $\ddot{r}_x$ is the linear acceleration of the origin of the rotating coordinate system in the X direction.

For the other point on the axis

$$(3') \quad a_1'(x) = \ddot{r}_x + \dot{w}_y r_1'(z) - \dot{w}_z r_1'(y) + w_x \left[w_y r_1'(y) + w_z r_1'(z)\right] - r_1'(x) \quad w_y^2 + w_z^2$$

Subtracting (3') from (3) we get

$$(4) \quad a_1(x) - a_1'(x) = \left[r_1'(x) - r_1(x) \quad (w_y^2 + w_z^2)\right]$$

since $r_1(z) = r_1'(z)$ and $r_1(y) = r_1'(y)$.

Similarly

$$(5) \quad a_2(y) - a_2'(y) = \left[r_2'(y) - r_2(y)\right] \quad (w_z^2 + w_x^2)$$

$$(6) \quad a_3(z) - a_3'(z) = \left[r_3'(z) - r_3(z)\right] \quad (w_x^2 + w_y^2)$$

The quantities on the left hand side are the differences in accelerations in the respective x, y, z directions between two points, rigidly connected, due to an angular rotation about a certain origin. Therefore, the acceleration can be called simply the reading of an accelerometer placed at that point, since an accelerometer placed on the x axis will only record acceleration along the x axis. This net acceleration is due to rotation about the y and z axis only.

Calling the accelerometer readings on the x axis A_1 and A_2, on the y axis A_5 and A_6, and on the z axis A_4 and A_3, and using the notation

$$(7)\quad -K = \frac{a_1(x) - a_1'(x)}{r_1'(x) - r_1(x)} = \frac{A_1 - A_2}{r_1'(x) - r_1(x)} = w_y^2 + w_z^2$$

$$(8)\quad -K_3 = \frac{a_2(y) - a_2'(y)}{r_2'(y) - r_2(y)} = \frac{A_5 - A_6}{r_2'(y) - r_2(y)} = W_z^2 + w_x^2$$

$$(9)\quad -K_2 = \frac{a_3(z) - a_3'(z)}{r_3'(z) - r_3(z)} = \frac{A_3 - A_4}{r_3'(z) - r_3(z)} = w_x^2 + w_y^2$$

Adding (7) + (8) + (9) gives

$$-(K_1 + K_2 = K_3) = 2(w_x^2 + w_y^2 + w_z^2)$$

Since $w^2 = w_x^2 + w_y^2 + w_z^2$

$$(10)\quad w = 1(K_1 + K_2 + K_3)/2$$

Also

$$(11)\quad w_x = \sqrt{1(-K_1 + K_2 + K_3)/2}$$

$$(12)\quad w_y = \sqrt{(K_1 + K_2 + K_3)2}$$

$$(13)\quad w_z = \sqrt{(K_1 - K_2 + K_3)/2}$$

Equation (10) predicts the angular velocity about the origin of the moving or fixed system.

Equations (11), (12), (13) give the component of that angular velocity with respect to the fixed system, but do not determine the direction of w_x, w_y, w_z.

From this discussion it is apparent that all six accelerometers must record accurately and be readable for the computations to have meaning. Further, the distance between the accelerometers must be accurately known if the computations are to be accurate; therefore, the kit must be built to record accurately and the instruments used must be highly sensitive. Moreover, it is impossible to determine, from the original accelerometer traces on the oscillograph, the rate of rotation. In other words, the variation of any individual accelerometer is completely independent of the rate of rotation.

The center of rotation of such a system is without physical meaning when the system is allowed to rotate in three dimensions. If rotation about two of the axes is neglected, then it is possible to define the axis of rotation.

The method used to reduce the data was to read the oscillograph traces and transfer the digital data to IBM cards. The computation to predict rate of rotation was done on the Datatron. A GSAP film was also used as a rough measurement of the rate of rotation. This GSAP film was compared to the computed values for those drops on which all six accelerometers recorded satisfactorily. The best way to find the point about which the dummy rotates is not by using the kit, but by placing the accelerometers on the dummy itself, and from these accelerometers, determine which records the highest; that accelerometer will be farthest away from the center of rotation.

MISSION PROFILE

In order that the reader may appreciate what is considered a successful mission and understand how it is accomplished, a profile of the desired mission is being inserted at this point. Due to the many systems and the complexities entailed in a mission, it will be observed under, "Test Results", that many mistakes were made and many new problems arose with every modification of the over-all system.

Here, in brief, is the basic mission profile:

a. All instruments and wiring were checked and tested for continuity. If everything was found to be in order, the oscillograph magazine was loaded and the kit calibrated according to a prescribed check list. (Fig. 4). The calibration was developed and inspected by a responsible technician, and if all instruments were not recording correctly, the discrepancy was located, repaired, and a recalibration made. When everything performed as required, the oscillograph magazine and camera were loaded, the battery pack installed, the kit checked out with the balloon cut-down box, a final "laboratory check" made, (Fig. 17), and the kit was closed up, ready to fly. A recovery notice was then taped on one side of the kit.

b. The dummy was suspended and adjusted to the desired body configuration and all joints checked for rigidity. Back accelerometers were mounted, and the dummy was dressed in a fluorescent red flying suit, and the main personnel parachute was attached. After the parachute was adjusted, the feet were tied together, the arms tied down, and the hands and fingers taped snugly to the body. (Nylon webbing was used in tying the limbs to the body.) A recovery notice was taped on an exposed area, usually the leg, and the dummy was ready to fly.

c. All equipment was taken to the launch area and weighed to determine the payload in order to compute the amount of helium required to obtain the desired lift from the balloon. The balloon cut-down box was attached to the bottom of the balloon and raised off the ground by a mobile crane. The dummy was then attached below the balloon cut-down box by threading a piece of nylon webbing through a ring on the dummy's head, a D-ring on the cut-down box and two squib-fired cutters which were activated through the cut-down box by radio-command at dummy release time. The instrument kit was installed on the dummy, all connections between the various systems were made and then safetied, parachute static lines were connected to their respective attachment points, and a thorough check made on the over-all system. While the equipment was being installed and inspected on the bottom of the balloon, the upper portion was being inflated. When inflation was complete and all connections given a final inspection, the area was cleared, in preparation for the launch. The upper portion of the balloon was released by triggering the launch arms, and the balloon rose until it was arrested by the attachment to the crane. The crane was then positioned to the best direction for releasing the balloon. This accomplished, a squib was fired, cutting the balloon-crane attachment, and the balloon began its ascent.

FINAL CHECK IN LAB

1. Calibration records
2. 2 Galvo plugs
3. 1 Remote plug
4. 1 Oscillograph power
5. Off - on Switch ON
6. Light intensity
7. Dust tapes
8. Paper capacity
9. Short run
10. Timer set with oscillograph Off
11. Off - On Swith ON
12. GSAP Power pktg
13. GSAP film loaded
14. F - stop #4
15. Battery power
16. Short Burst on GSAP

PRE FLIGHT CHECK AT LAUNCH

1. Run Oscillograph
2. Run GSAP
3. Check Squib

Figure 17. Laboratory and Pre-Launch Check List

d. When the balloon attained the desired altitude, a radio-command cut-down signal was transmitted to a receiver installed in the cut-down box which in turn released voltage to the dummy instrument kit, warming it up. Fifteen seconds after the initial transmission, cut-down was effected by the dummy's instrument kit shooting voltage to the squibs, causing them to fire and thus releasing the dummy.

e. As the dummy fell away, the main parachute static line was pulled, arming the automatic aneroid timer installed in the parachute pack. During the free fall the instrument kit recorded every motion of the dummy. At 15,000 feet MSL, the automatic timer fired, deploying the main personnel canopy. As the dummy passed 12,000 feet MSL, the instrument kit was turned off and released from the dummy by another aneroid timer, and the instruments descended on their own parachute, deployed, as the kit fell from the dummy, by a static line attached to the main parachute harness.

f. The recovery crews, which were dispatched to the field prior to launch, recovered the equipment with the aid of radio directions and visual contact with the recovery aircraft. When the crews returned to the laboratory with the equipment, it was opened, the film removed and sent to be developed, and the instruments checked again for continuity. As the film was returned, it and the corresponding calibrations were sent to the data-reducing agency for final reduction and return to the project engineer.

TEST RESULTS

The unstabilized dummy drops were conducted in two stages. The first stage, drops 001 through 035, was concerned primarily with testing equipment. The test vehicle used was a C-97 flying at 25,000 to 31,000 feet MSL with 160 to 175 knots indicated air speed. On the remaining drops, 036 through 057, balloons served as test vehicles. Test results were:

Drop 003: Altitude - 30,891 feet, free fall - 85 seconds. A peak rotation of 92 rpm was recorded for 12 seconds.

Drop 005: Altitude - 30,913 feet, free fall - 86 seconds. Faulty instrumentation restricted collection of usable data.

Drop 007: Altitude - 30,996 feet, free fall - 90 seconds. Peak rotation recorded was 102 rpm for 9 seconds.

Drop 009: Altitude - 30,965 feet, free fall - 82 seconds. Rotation encountered in this drop was not sufficient to merit computation.

Drop 010: Altitude - 31,004 feet, free fall - 84 seconds. Due to erroneus tracking, the peak rotation recorded was 60 rpm for 2 to 3 seconds.

Drop 011: Altitude - 30,956 feet, free fall - 86 seconds. Faulty instrumentation did not allow accurate determination of dummy's attitude during the fall.

Drop 013: Altitude - 30,933 feet, free fall - 85 seconds, A peak rotation of 75 rpm was recorded for 5 seconds before data became illegible.

Drop 014: Altitude - 31,021 feet, free fall - 85 seconds. A peak of 70 rpm was recorded for 3 seconds, with the majority of the fall recording an average of 45 to 50 rpm.

Drop 015: Altitude - 30,994 feet, free fall - 87 seconds. A coning motion of 40 rpm was recorded throughout almost the entire fall.

Drop 016: Altitude - 30,958 feet, free fall - not recorded. This dummy free-fell to the ground due to a faulty type F-1A automatic parachute release.

Drop 017: Altitude - 31,033 feet, free fall -77 seconds. A peak rotation of 75 rpm was recorded for 12 seconds, and an average of 50 to 60 rpm recorded throughout the fall.

Drop 018: Altitude - 31,020 feet, free fall - 84 seconds. Poor image definition and contrast on the film resulted in no data for this drop.

Drop 020: Altitude - 30,637 feet, free fall - 82 seconds. Poor image quality resulted in no data.

Drop 021: Altitude - 30,420 feet, free fall - 82 seconds. Dummy had an average spin of approximately 40 rpm with a peak of 46 rpm for 8 seconds.

Drop 022: Altitude - 30,694 feet, free fall - 82 seconds. No data obtained due to poor image on film.

Drop 023: Altitude - 30,623 feet, free fall - 83 seconds. This dummy rotated along a lateral axis at an average of 60 rpm. The characteristic "flat spin" was not encountered here.

Drop 024: Altitude - 30,637 feet, free fall - 80 seconds. No data obtained due to faulty film.

Drop 025: Altitude - 30,444 feet, free fall -90 seconds. Dummy had an average rotation of 35 rpm.

Drop 026: Altitude - 30,419 feet, free fall - not recorded. Complete data was not obtained, but recorded rotation averaged 20 rpm.

Drop 027: Altitude - 30,265 feet, free fall - 83 seconds. Dummy was relatively stable with the exception of a rotation of 45 rpm for 10 seconds.

Drop 028: Altitude - 30,565 feet, free fall - 83 seconds. Dummy rotated 60 rpm during this fall.

Drop 029: Altitude - 30,509 feet, free fall - 87 seconds. An average of 25 rpm was recorded.

Drop 030: Altitude - 30,468 feet, free fall - 88 seconds. A coning motion of 10 rpm was recorded throughout this fall.

Drop 031: Altitude - 27,647 feet, free fall - 55 seconds. Subject rotated at an average of 12 rpm.

Drop 032: Altitude - 27,555 feet, free fall - 53 seconds. This subject averaged 46 rpm in a coning motion.

Drop 033: Altitude - 25,989 feet, free fall - 50 seconds. Subject rotated at an average of 47 rpm.

Drop 034: Altitude - 25,788 feet, free fall - 47 seconds. Low and varying rotation occurred on this drop, as subject was constantly changing body configuration.

Drop 035: Altitude - 31,373 feet, free fall - 67 seconds. Dummy coned at 24 rpm throughout the entire fall.

During the above drops, modifications were continually being made in instrumentation and hardware, until the desired kit and equipment resulted. On the tests, dummies were dropped with and without chest reserve parachutes to determine whether or not the aerodynamic characteristics of the free falling body were greatly altered by the presence or absence of the reserve, but no decisive change was noted.

The body position decided on for the balloon-dummy tests was:

Hands and arms rigid and tied to the body,

Knees flexed and rigid,

Hips slightly bent and rigid, and

Feet tied together.

The limbs were tied to reduce the possibility of the dummy flailing and getting tangled up in the suspension lines at parachute opening. This configuration most closely simulated that of an unconscious person descending from altitude.

On completion of the C-97 program in April 1954, all equipment was returned to WADC for repair and servicing, and for use as patterns in the fabrication of new kits and equipment to be used on the balloon-dummy drops.

In June 1954, the project engineer returned to HADC with the new equipment, and the second stage of the unstabilized dummy drops began.

Drop 036: Balloon was a Winzen 45 foot polyethylene type, designed to carry its payload to 60,000 feet. Platform launch used. Balloon rose 30 feet in air, then descended. Malfunction was not determined.

Drop 037: Balloon was same as above. Platform launch. Balloon ascended to 25 feet and began descent. More helium was pumped into balloon which then ascended to 53,000 feet. During this period, time on the mechanical clock ran out and cut-down was initiated. Two open canopies were observed immediately following cut-down. Recovery of the packages revealed that the instrument kit had separated on cut-down, probably due to the quick release clamps failing. No data was obtained.

Drop 038: Winzen 61-foot polyethylene designed to reach 77,000 feet. "Covered Wagon" launch. Ascent was slow, and the clock initiated cut-down at 48,900 feet. Inspection revealed that kit and dummy separated at cut-down and no data was obtained. Due to this failure, and extensive study of the materials and methods being used was conducted. The results of the study were: New, stronger quick release clamps were designed and fabricated, as many protruding surfaces as possible were removed, smoke grenades were to be tried during free fall instead of after parachute deployment, a more positive system of helium measurement was to be incorporated by HADC, and a new type of cut-down system was developed.

Drop 039: Winzen 116-foot tape balloon. Vertical launch used. Balloon developed a hole at 5,000 feet, and settled slowly to earth. No data was obtained.

Drop 040: Winzen 83-foot tape balloon. Vertical launch used. Balloon burst at 44,000 feet, and the dummy descended attached to the balloon cut-down box. No data was obtained.

Drop 041: Winzen 83-foot tape balloon. Vertical launch used. Balloon ascended to 80,000 feet, but, due to improper installation of the dummy cut-down system, the dummy failed to separate from the balloon cut-down box. No data was obtained.

Drop 042: Winzen 83-foot tape balloon. Vertical launch used. Balloon ascended to 75,000 feet. Following cut-down, the dummy assumed a prone position and began rotating in a horizontal plane. The rotation remained constant at 40 rpm and was accompanied by a 30° oscillation, 30 oscillations per minute. Total free fall time was 170 seconds.

Drop 043: Winzen 83.3-foot balloon. Vertical launch used. Balloon ascended to 76,000 feet. Development of film and oscillograph paper revealed that instrumentation had been activated prior to launch. No data was obtained.

Drop 044: Winzen 83.3 tape balloon. Vertical launch used. Balloon ascended to 75,000 feet. The dummy, when released, fell stable for 10 to 15 seconds, then assumed a prone position and began a rotation which gradually increased to 102 rpm. Total free fall time was 140 seconds. Rotation averaged 40 rpm for 69 seconds.

Drop 045: Winzen 83.3-foot tape balloon. Vertical launch used. Balloon ascended to 75,000 feet. Dummy's fall was stable for 10 to 15 seconds. In 8 seconds, rotation increased from 0 rpm to a maximum of 166 rpm. Highest average was 135 rpm for 24 seconds. After 24 seconds of violent spinning, dummy became relatively stable and fall was accompanied by oscillation and 25 rpm rotation. Total free fall time was 145 seconds.

Drop 046: Winzen 116-foot tape balloon. Vertical launch used. Balloon, with two dummies, ascended to 40,000 feet, then burst. An automatic safety released the dummies at 30,000 feet. One quick-release clamp failed on Dummy #1, making data unusable. Dummy #2 reached a peak rotation of 167 rpm and had an average rotation of 127 rpm for 18 seconds. The dummy was spinning at 108 rpm when parachute deployed, and camera in kit showed a perfect "Mae West" in the canopy. This may have been a result of the rotation. The total free fall time was 66 seconds.

Drop 046 was performed without the use of an insulation bag to facilitate work on the dummies and instrumentation immediately prior to launch. Since the instruments functioned properly, it was decided to conduct future tests without the bag.

Drop 047: Winzen 95-foot tape balloon. Vertical Launch used. Balloon, with one dummy, ascended to 76,000 feet. At cut-down, the dummy fell stable for 3 seconds, then assumed a prone position and began rotating. An average of 135 rpm was recorded for 7 seconds, with a peak of 145 rpm. Immediately on reaching the peak rpm, the kit separated from the dummy, and data was not obtained for the complete fall.

Drop 048: Winzen 95-foot tape balloon. Vertical launch used. Balloon ascended to 78,000 feet with one dummy. Data from this drop was not analyzed.

Drop 049: General Mills 128-foot tailored tapeless balloon. Vertical launch used. Balloon ascended to 91,000 feet, but at launch, the dummies were dragged along the ground, and the kits separated. No data was obtained.

Drop 050: Winzen 95-foot tape balloon. Vertical launch used. Balloon, with one dummy, ascended to 86,000 feet. Following cut-down the dummy fell stable for 10 seconds, then began rocking in a prone position. The oscillation changed to a spin around a longitudinal axis through the body. The spin would increase to 95 rpm, decrease to 75 rpm, and increase again. This undulating type of motion was recorded until the dummy passed 12,000 feet, at which time the kit separated. Due to a parachute malfunction, the dummy free-fell to the ground. An average longitudinal spin of 83 rpm, with a peak of 102 rpm, was recorded for 80 seconds.

Drop 051: This drop consisted of two dummies dropped with stabilizing rigs, and will not be discussed in this report.

Drop 052: General Mills 128-foot tailored tapeless balloon. Vertical launch used. Dummies cut down immediately after the balloon was launched. The malfunction was attributed to a faulty aneroid safety device. No data was obtained.

Drop 053: General Mills 128-foot tailored tapeless balloon. Vertical launch used. Balloon ascended to 89,000 feet with two dummies. On recovery of the packages, it was discovered that the instrument kit from Dummy #1 had free-fallen and was damaged beyond repair. Inspection revealed that the kit recovery parachute static line had not been connected to the main parachute harness. The data, however, was reduced, and showed that the dummy had reached a peak rotation of 120 rpm. Dummy #2 had a peak rotation of approximately 200 rpm.

Drop 054: Winzen 116-foot tape balloon. Vertical launch used. Cut-down sequence started while the balloon was still attached to the crane. Explanation of the malfunction, given by Balloon Unit personnel, was, "false radio-command-activated sequence." Equipment was slightly damaged.

Drop 055: Winzen 116-foot tape balloon. Vertical launch used. Balloon ascended to 47,000 feet, then burst. A review of proceedings showed that balloon had insufficient payload, and ascent was too rapid for balloon's expansion capabilities. No data was obtained.

Drop 056: General Mills 128-foot tailored tapeless. Vertical launch used. Balloon, with two dummies, (one stabilized, one unstabilized), ascended to 89,000 feet. Unstabilized dummy began rotation immediately, and reached a peak of 83 rpm, with an average of 80 rpm for 7 seconds.

Drop 057: General Mills 128-foot tailored tapeless balloon. Vertical launch used. Balloon, with two dummies (one stabilized, one unstabilized) ascended to 90,300 feet. Unstable dummy began rotation immediately and reached peak of 106 rpm.

The following page presents in chart form a summary of those launches which recorded valid data, and the ensuing pages contain graphs, showing typical example of data reduction.

BALLOON - DUMMY LAUNCHES RECORDING VALID DATA

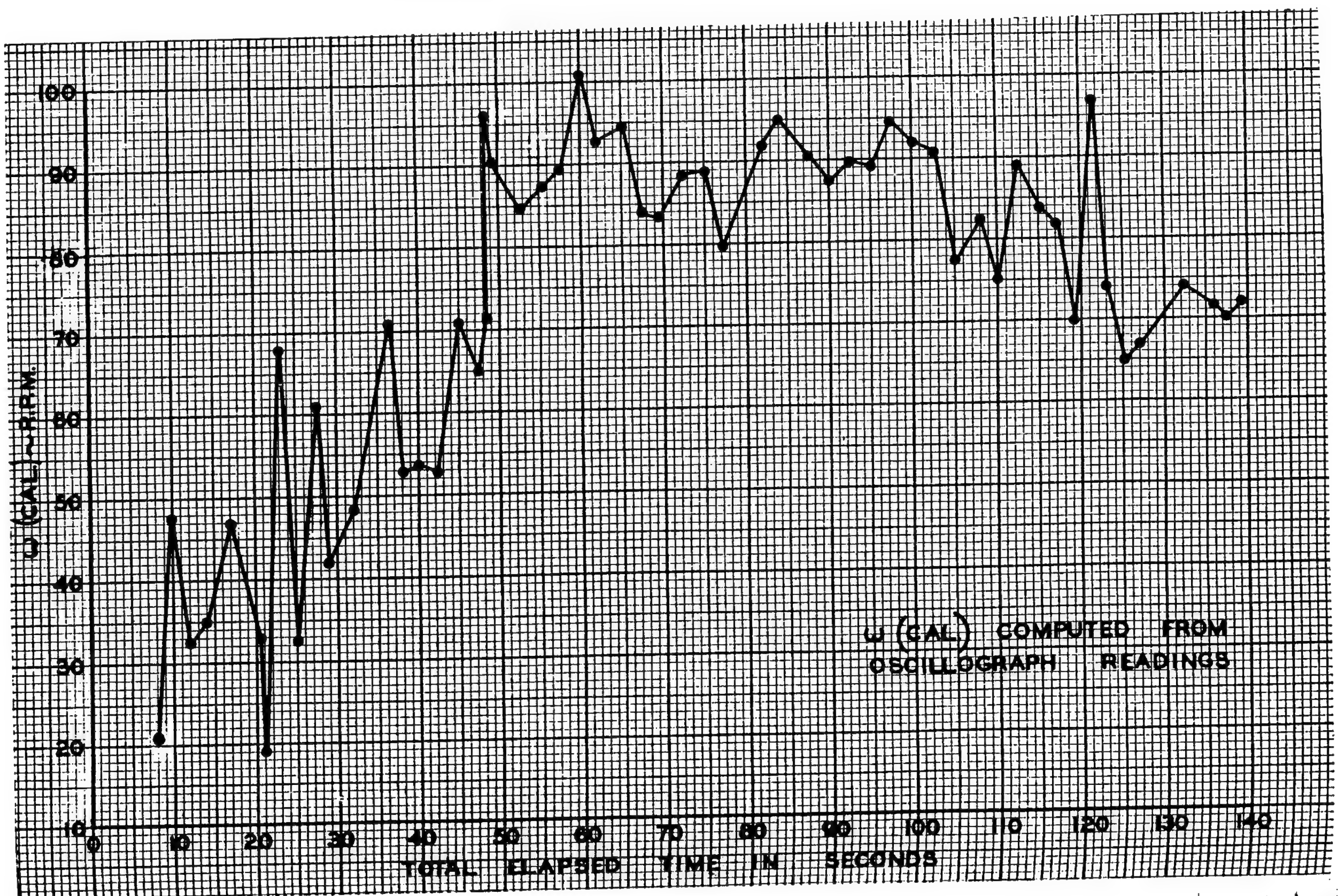
Drop No.	Date	Balloon *Note	Launch	Altitude	Peak RPM	Average RPM and Time
042	9 Dec. '54	W 83.3ST	Vertical	75,000 ft.	40	30 RPM for 120 seconds
044	1 Mar. '55	W83.3ST	Vertical	75,000 ft.	102	40 RPM for 69 seconds
045	3 Mar. '55	W83.3ST	Vertical	75,000 ft.	166	135RPM for 24 seconds
046	15 June '55	W116ST	Vertical	40,000 ft.	167	127 RPM for 18 seconds
047	23 June '55	W95ST	Vertical	76,000 ft.	145	135 RPM for 7 seconds
050**	15 July '55	W95ST	Vertical	86,000 ft.	102	83 RPM for 80 seconds
053	8 Feb. '56	GM128TT	Vertical	89,000 ft.	120 200	110 RPM for 12 seconds #2 not analysed
056	18 May '56	GM128TT	Vertical	89,000 ft.	83	70 RPM for 14 seconds
057	22 May '56	GM128TT	Vertical	90,300 ft.	106	75 RPM for 10 seconds

* Note - Balloon symbols are: W - Winzen; ST - Stress Tape; GM - General Mills; and TT - Tailored Tapeless. The numbers denote the diameter of the Balloon.

** This drop was unusual in that the spin was about an axis running longitudinally through the prone body, rather than about a vertical axis perpendicular to the earth's surface. Drops 023 (C-97)program) and 050 were the only drops recording spin about the lateral axis.

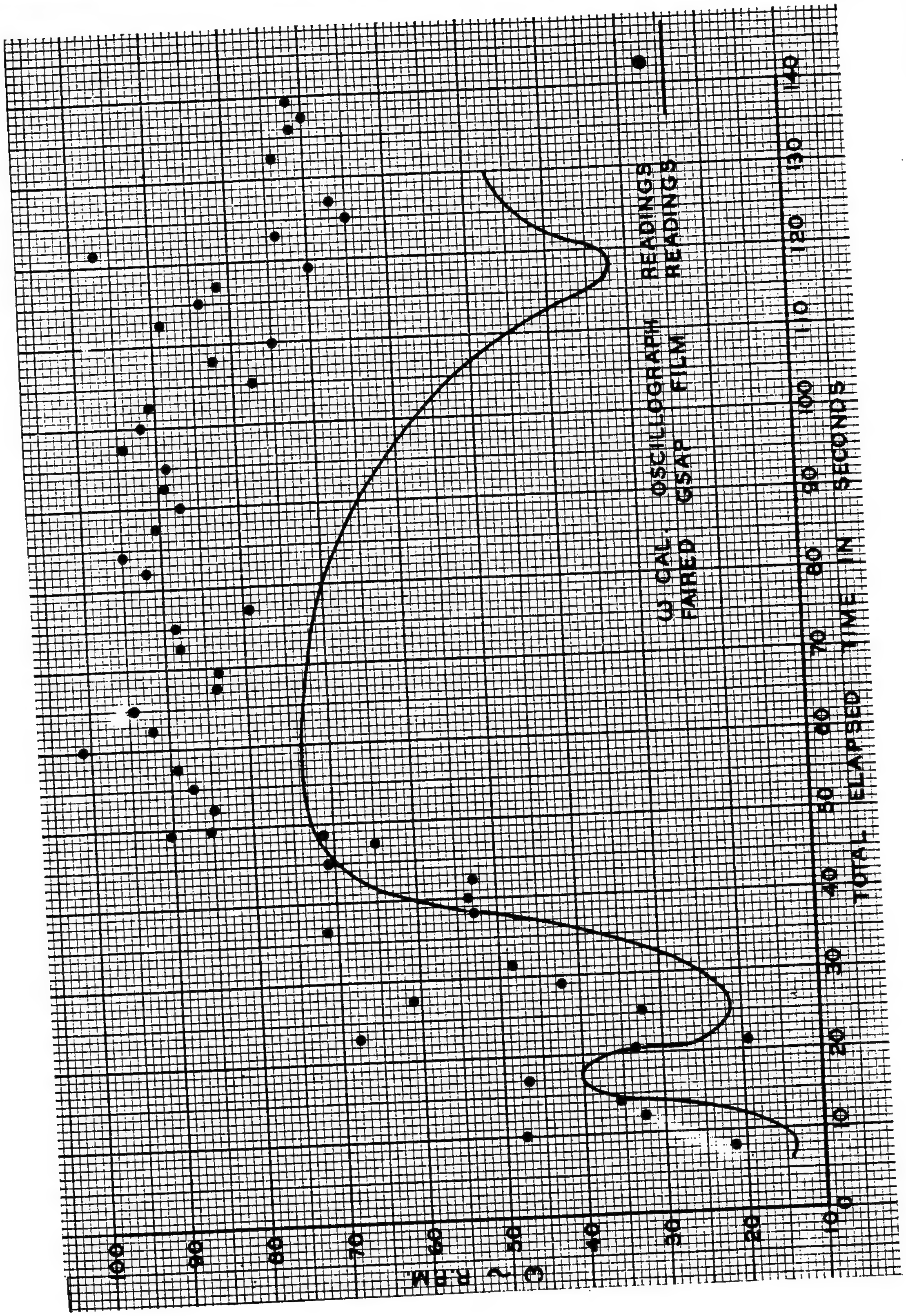
DROP NO. 044

1 March 1955



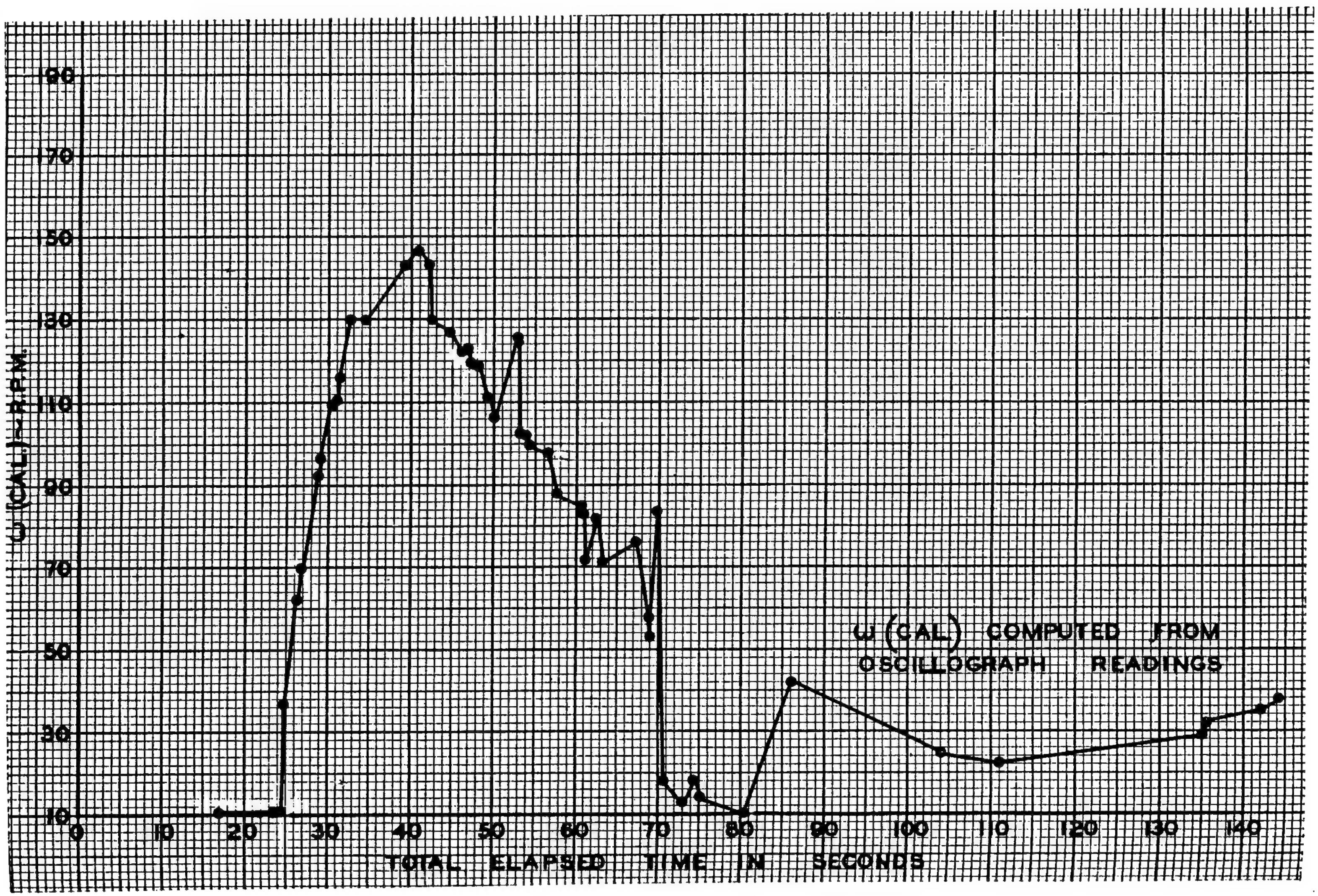
DROP NO. 044

1 March 1955



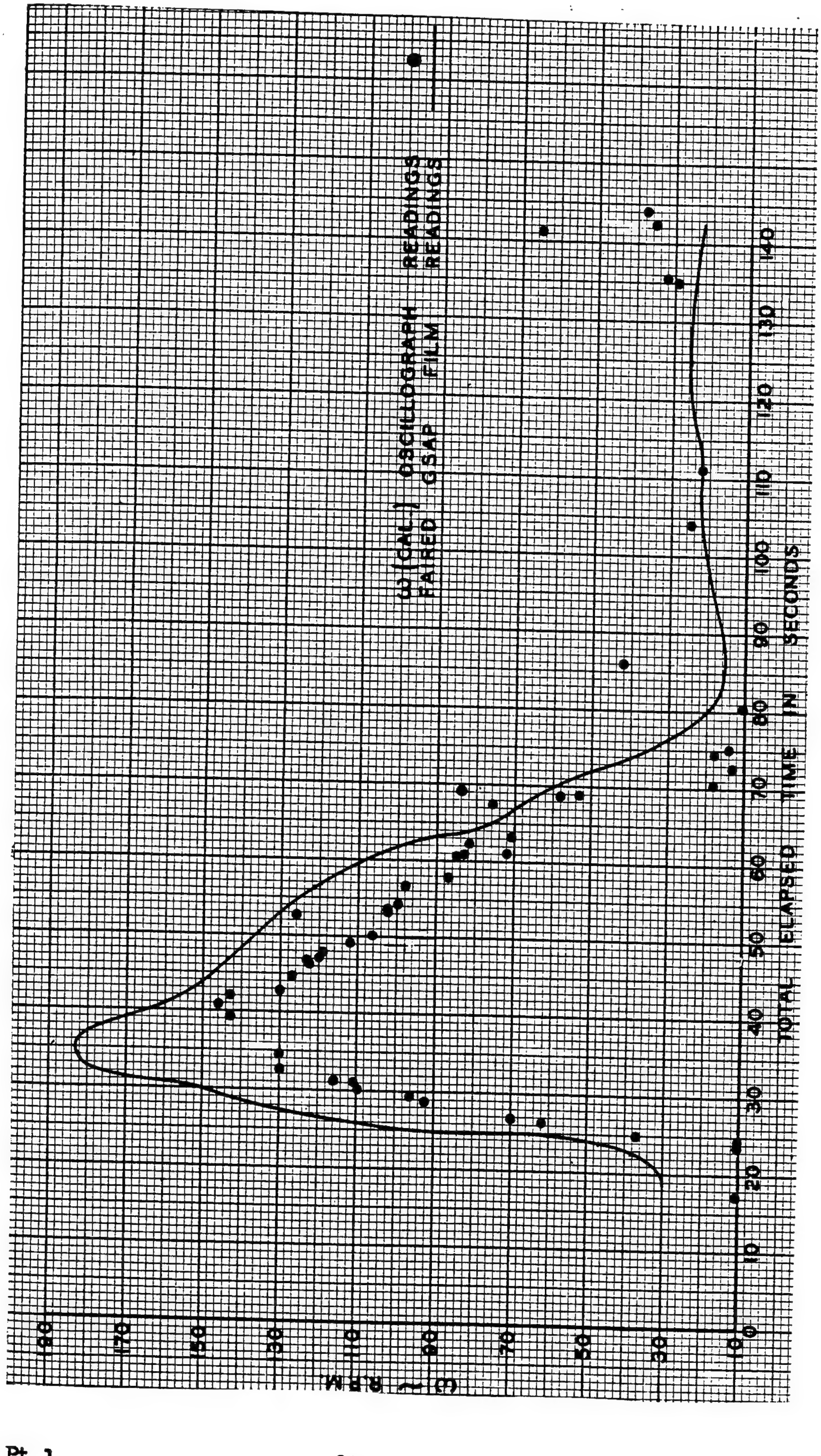
DROP NO. 045

3 March 1955

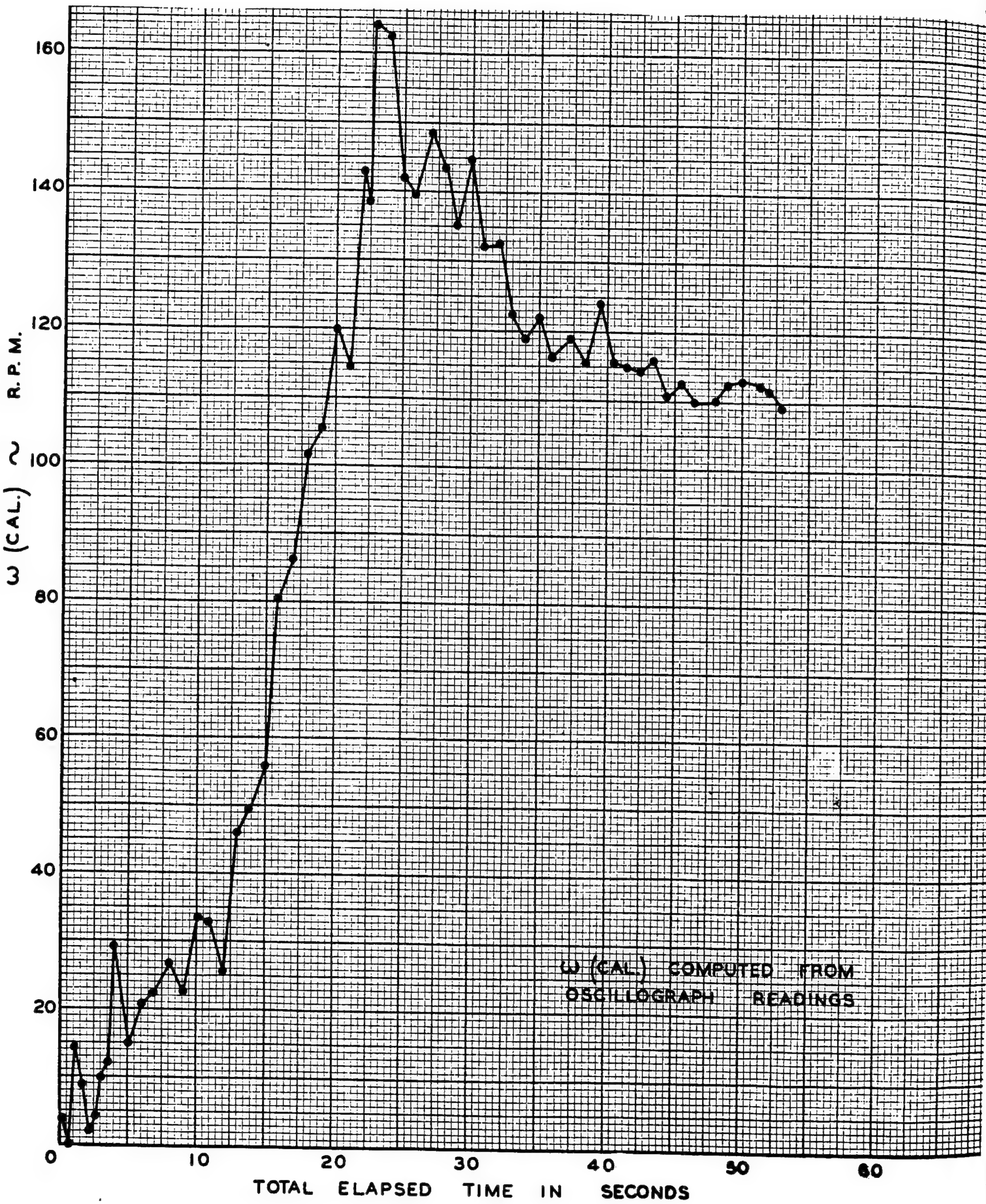


DROP NO. 045

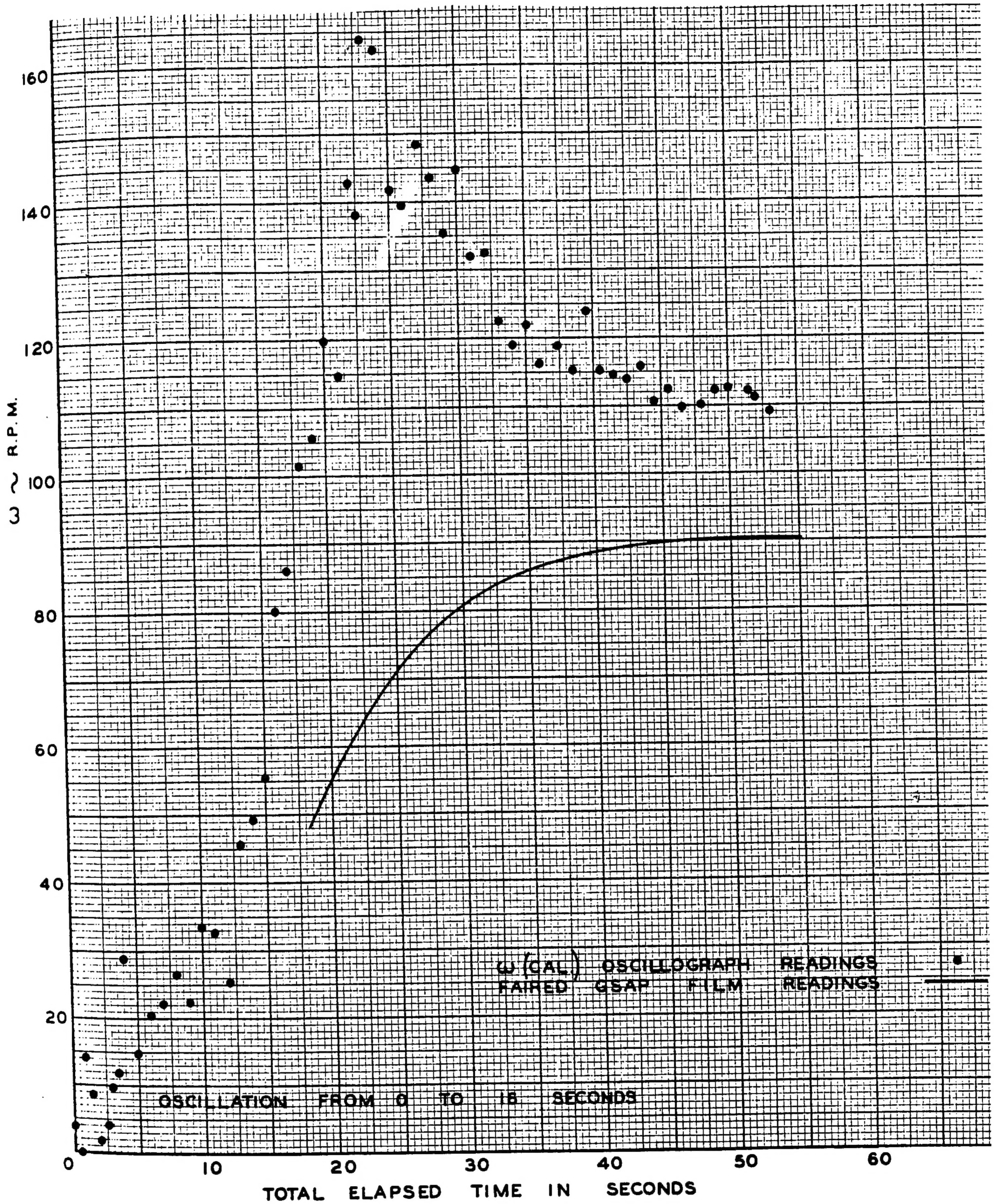
3 March 1955

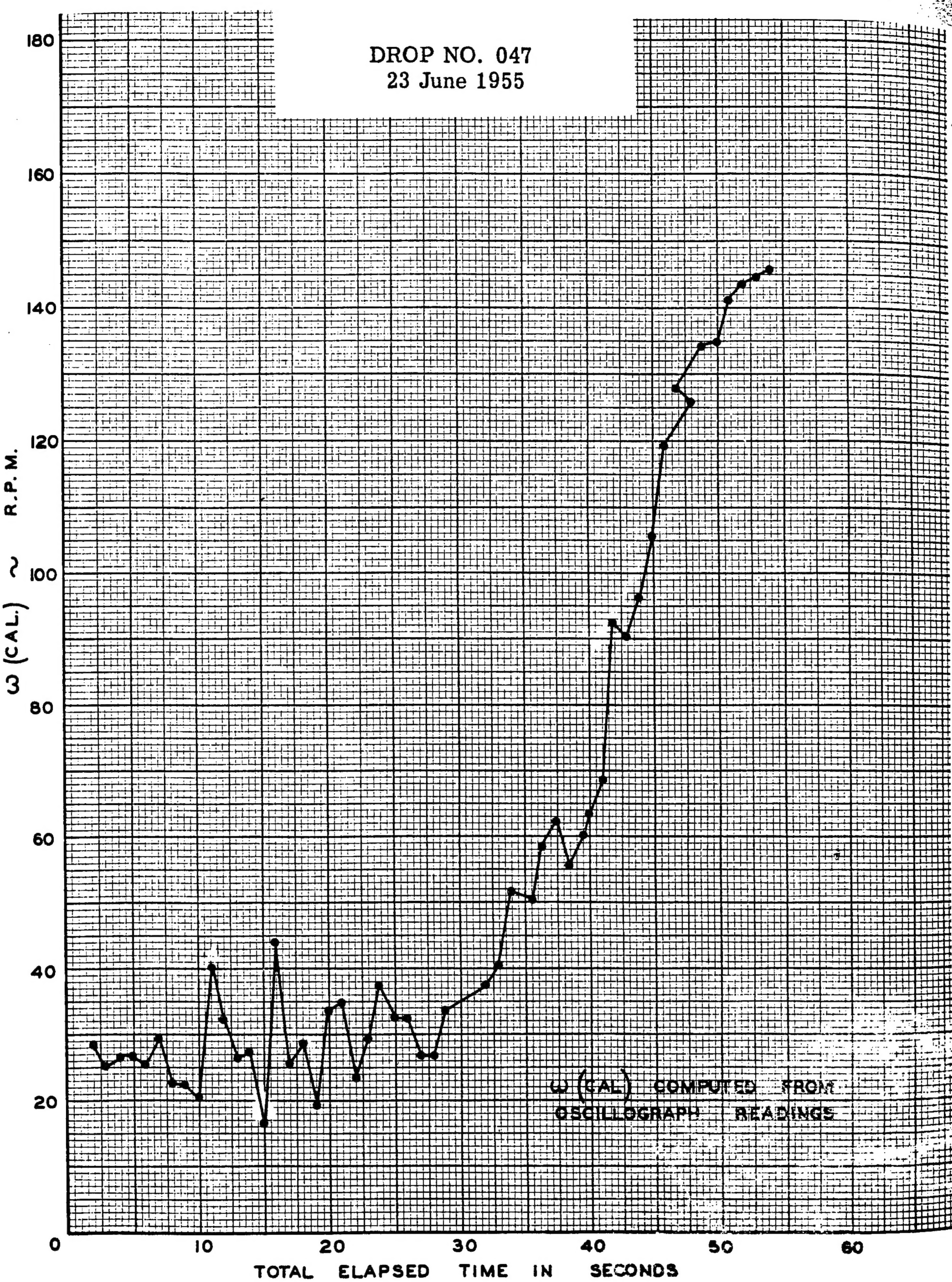


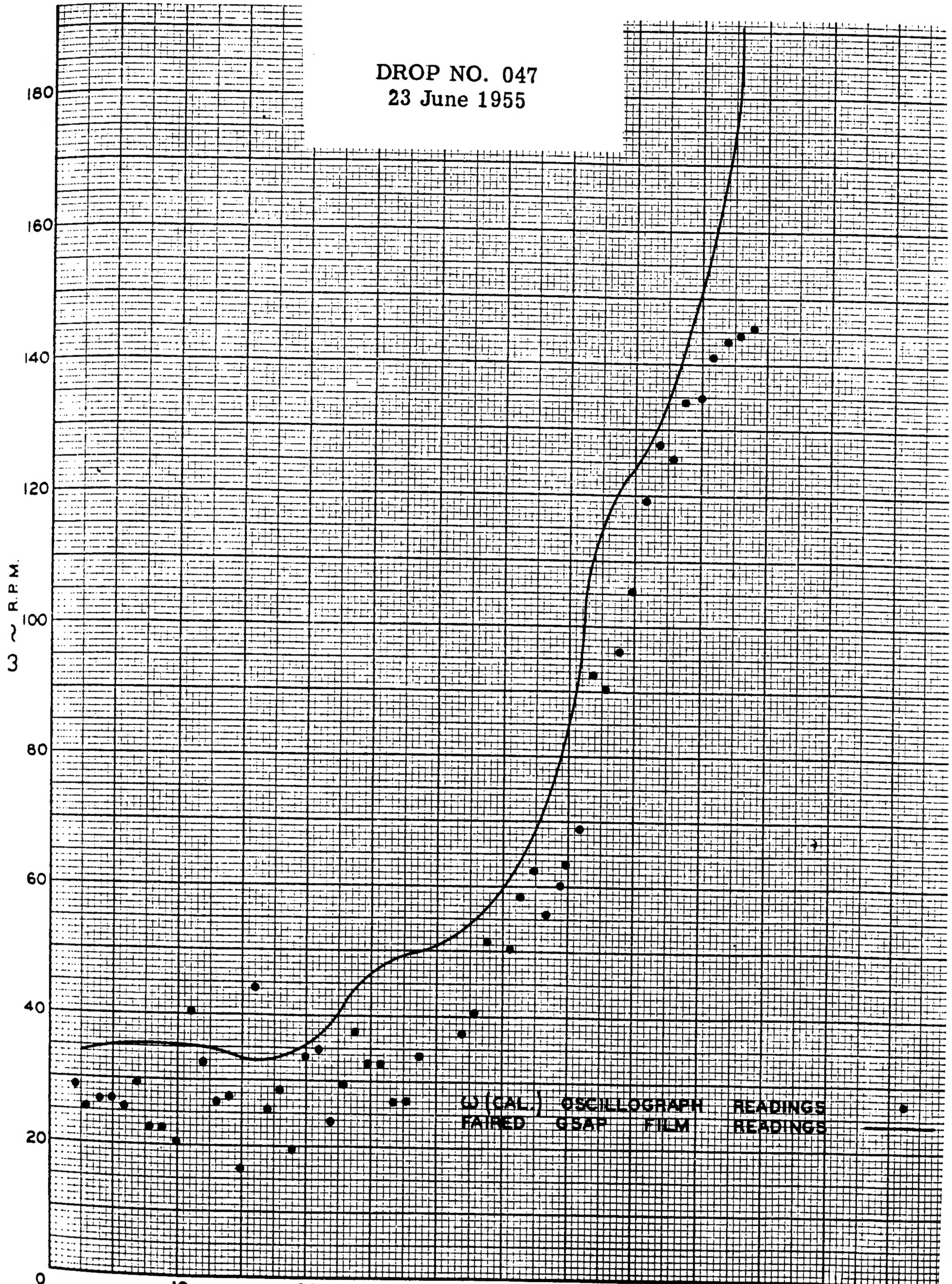
DROP NO. 046
15 June 1955



DROP NO. 046
15 June 1955




DROP NO. 047
23 June 1955
ω (CAL.) ~ R.P.M.
180
160
140
120
100
80
60
40
20
0
10
20
30
40
50
60
TOTAL ELAPSED TIME IN SECONDS
ω (CAL) COMPUTED FROM
OSCILLOGRAPH READINGS


DROP NO. 047
23 June 1955
ω ~ R.P.M.
0
20
40
60
80
100
120
140
160
180
10
20
30
40
50
60
TOTAL ELAPSED TIME IN SECONDS
ω (CAL.) OSCILLOGRAPH READINGS
FAIRED GSAP FILM READINGS

SECTION III

CONCLUSIONS

From the results of these tests, it is apparent that no man can be expected to free-fall, unstabilized, from high altitude without a very strong possibility of severe spinning and/or tumbling which would cause injury or death, either directly or indirectly. Therefore, systems of stabilizing a free-falling body are being studied, and this stabilization study will constitute Part II of this report.